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Danish Atomic Energy Commission

Research Establishment Risö

Environmental Radioactivity in Denmark in 1965

by A. Aarkrog and J. Lippert

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Environmental Radioactivity in Denmark in 1965

by

A. Aarkrog and J. Lippert

The Danish Atomic Energy Commission
Research Establishment Risö
Health Physics Department

Abstract

The present report deals with the measurement of fall-out radioactivity in Denmark in 1965. Sr-90 was determined in samples from all over the country of precipitation, soil, ground water, sea water, grass, dried milk, fresh milk, grain, bread, potatoes, vegetables, fruit, total diet, drinking water, and human bone.

Furthermore Sr-90 was determined in local samples of air, rain water, grass, sea plants, animal bone, fish, meat, and human milk.

Cs-137 was determined in milk, grain products, potatoes, vegetables, fruit, total diet, pork, beef, and human milk samples, and Cs-137 was measured by whole-body counting in persons from a control group at Risö.

Estimates of the mean content of radiostrontium and radiocaesium in the human diet in Denmark in 1965 are given.

Finally the report includes, as previously, regular surveys of environmental samples from the Risö area.

Statens trykningskontor
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ACKNOWLEDGEMENTS

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The collection of samples from the waters round Sealand would have been impossible without the assistance of the Royal Danish Navy.

Our special thanks are directed to the staffs at the ten state experimental farms at Tylstrup, Ødum, Studsgård, Askov, St. Jyndevad, Blangstedgård, Tystofte, Virumgård, Abed, and Åkirkeby, who as in previous years have supplied a number of the most important samples dealt with in this report.

Finally we thank Mr. Heinz Hansen for valuable statistical advice, Mr. Arna Andersen for help in the planning of the greenhouse experiment mentioned in this report, Mr. Poul Abrahamsen for drawing the figures, and, last but not least, Mr. Flemming Steenbuch, who has been very helpful with the correction of the language in this report.

ABBREVIATIONS AND UNITS

FP	fission products
pCi	picocurie, 10^{-12}Ci, μμCi
nCi	nanocurie, 10^{-9}Ci, mμCi
mCi	millicurie, 10^{-3} Ci
MPC	maximum permissible concentration
c/min	counts per minute
d/min	disintegrations per minute
c/h	counts per hour
μR	micro-roentgen, 10^{-6} roentgen
S.U.	pCi Sr-90/g Ca, Sunshine unit
O.R.	observed ratio
M.U.	pCi Cs-137/g K, Moonshine unit
V	vertebrae
m	male
f	female
n Sr	natural (stable) Sr
eqv. μg U	equivalents ug uranium: activity as from 1 μ g U (~90 d/h)
eqv. mg KCl	equivalents mg KCl: activity as from 1 mg KCl (~0.88 d/min)
S.D.	standard deviation: $\sqrt{\frac{\Sigma (x-x_i)^2}{(n-1)}}$
S.E.	standard error: $\sqrt{\frac{\Sigma (x-x_i)^2}{n(n-1)}}$
U.C.L.	upper control level
L.C.L.	lower control level
Δ	one standard deviation due to counting
S.S.D.	sum of squares of deviations: $\Sigma (x-x_i)^2$
f	degrees of freedom

Samples:

H:	sea water
J:	soil
L:	air
B:	bed soil
Å:	eel
PG:	grass
PH:	sea plants
D:	drain water
S:	waste water
R:	precipitation
M:	milk

s^2	the variance
v^2	the ratio between the variance in question and the residual variance
P	probability fractile of the distribution in question
η	coefficient of variation

1. INTRODUCTION

1.1.

The present report is the tenth of a series of periodical reports (cf. refs. 1-9) dealing with measurements of radioactivity in Denmark.

A few alterations have been made in the sampling programme as compared with 1964. Fresh milk from the eight zones and Copenhagen was collected only in June and December. Grass and air samples, separately, from Risö were bulked into 3-monthly samples before the Sr-90 analysis. Milk and grass were not collected from the state experimental farms in June, only in September. Along with the total-diet samples in June and December, drinking water was collected from the 48 towns and from Copenhagen, and analysed for Sr-90.

Total α measurements on soil samples from Risö were not carried out in 1965.

1.2.

The methods of radiochemical analysis[10-12] and the statistical treatment of the results[13] are still based on the principles established in previous reports[3-6]. However, the natural logarithm (ln) has been used instead of the common logarithm (log) in the analysis of variance; this has the obvious advantage that the coefficient of variation, η, nearly equals the square root of the residual variance for $s^2 \leq 0.1$: $\eta = \sqrt{e^{s^2} - 1}$[14]. The analyses of variance with more than a few missing values are now performed on a GIER computer with a programme, VAR 3, developed by J. Vestergaard[20].

1.3.

The report does not include detailed tables of the total β measurements from the environmental control of the Risö site. These tables are available in the form of microcards at the library of the Danish Atomic Energy Commission at Risö.

1.4.

The report contains no information as regards sample collecting and analysis except in the cases where these procedures have been altered[7].

1.5.

The personnel of the Environmental Control Section of the Health Physics Department consisted in 1965 of one chemist, nine laboratory technicians, two men for sample collection, and two women for washing-up. As in the previous years, important assistance was obtained from the Section for Electronics Development, not only in the maintenance of the counting equipment, but also in the interpretation of the γ-spectra.

1.6.

The composition of the Danish average diet, used in this report, is identical with that proposed by the nutritional consultant to the Atomic Energy Commission, Professor E. Hoff-Jørgensen, Ph. D.

2. ORGANIZATION AND FACILITIES

Only minor alterations have taken place in the sample collection, preparation, analysis, and counting[15] as compared with the previous years. The Section for Electronics Development has developed and constructed a number of solid-state detectors (Si and Ge)[16], which are expected to be available for routine measurements of α- and γ-emitters, e.g. in air filters, in the coming years.

Fig. 3.1.1.1. Roskilde Fjord.

3. RISÖ ENVIRONMENTAL MONITORING IN 1965

3.1. Gross β-Activity

3.1.1. Sea water

Fig. 3.1.1.1 shows the sample locations in Roskilde Fjord. Figs. 3.1.1.2 - 3.1.1.4 show the control charts for HI, HIII-IV and H VII-X. The yearly mean for HI in 1965 was 53 eqv. mg KCl/2.5 g (in 1964: 69), for HIII-VI: 51 eqv. mg KCl/2.5 g (in 1964: 66) and for HVII-X: 53 eqv. mg KCl/2.5 (in 1964: 71). Fig. 3.1.1.5 shows the mean levels of radioactivity in sea salt since 1957.

The analyses of variance indicate that the variations between locations within H III-VI and within H VII-X were insignificant. The variations between days were highly significant (P > 99.95%). The residual error of the sea-water activity determinations was approx. 7%.

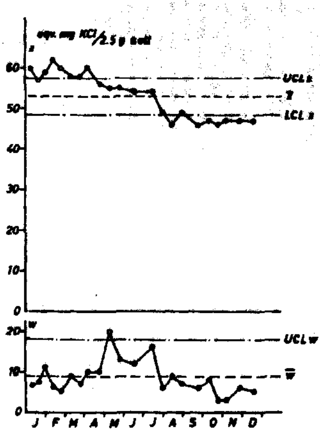

Fig. 3.1.1.2. Control chart for H I, 1965.

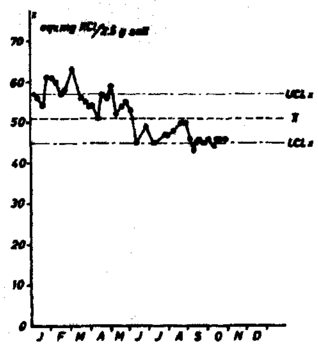

Fig. 3.1.1.3. Control chart for H III-IV, 1965.

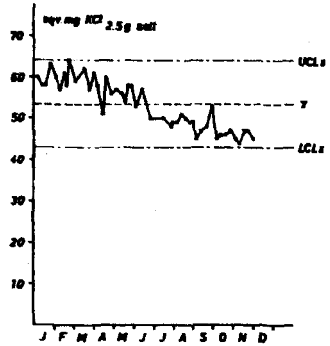

Fig. 3.1.1.4. Control chart for H VII-X, 1965.

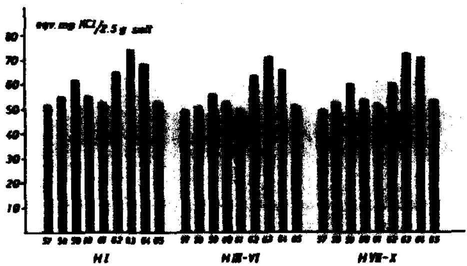

Fig. 3.1.1.5. Mean radioactivity in sea water, 1957-65.

3.1.2. Soil

Figs. 3.1.2.1 - 3.1.2.2 show the sample locations for land samples in the environment of Risö.

Figs. 3.1.2.3 - 3.1.2.5 contain the control charts for J I, J II-III and J IV-V. The yearly mean for J I in 1965 was 156 eqv. mg KCl/3.0 g soil (in 1964: 226), for J II-III: 151 eqv. mg KCl/3.0 g (in 1964: 203) and for J IV-V: 138 eqv. mg KCl/3.0 g (in 1964: 195). Fig. 3.1.2.6 shows the mean levels of radioactivity in soil since 1957. The analyses of variance indicate a highly significant variation between J I locations (P > 99.95%), between J IV-V locations (P > 99.9%) and probably between J II-III locations (P > 95%). The variation between days was significant for J II-III (P > 99.95%), for J I (P > 99.95%) and for J IV-V (P > 99.5%). The relative residual error of the soil activity determinations was approx. 15%.

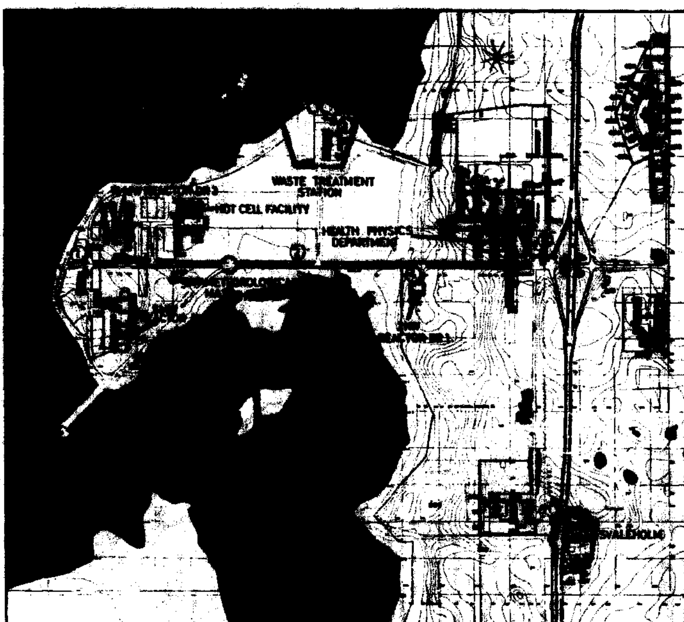

Fig. 3.1.2.1. The Risø Research Establishment.

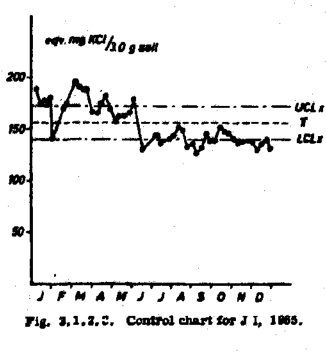

Fig. 3.1.2.3. Control chart for J I, 1965.

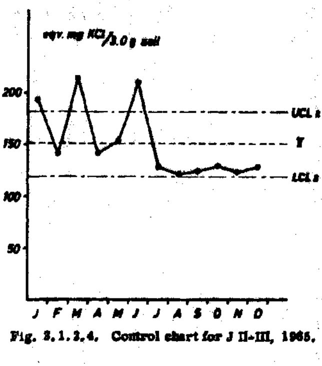

Fig. 3.1.2.4. Control chart for J II-III, 1965.

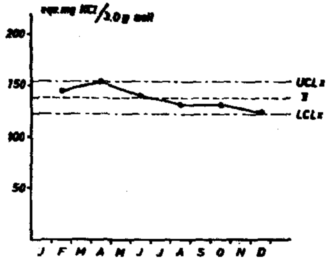

Fig. 3.1.2.5. Control chart for J IV-V, 1965.

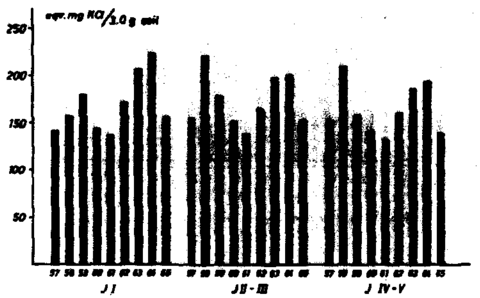

Fig. 3.1.2.6. Mean radioactivity in soil, 1957-65.

3.1.3. Air

Fig. 3.1.3.1 shows the diagram for FP activity in air samples in 1965. The mean value for the year was 0.33 eqv. mg KCl/m^3 as compared with 1.3 eqv. mg KCl/m^3 in 1964.

Fig. 3.1.3.2 shows the mean FP levels in air since 1957.

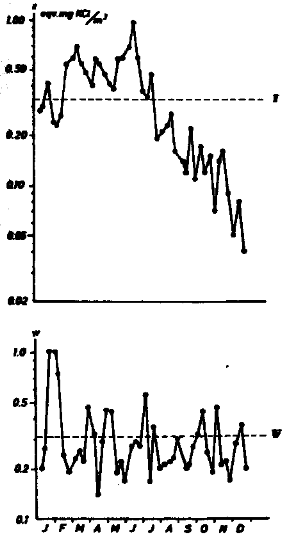

Fig. 3.1.3.1. Control chart for L F, 1965.

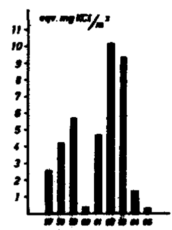

Fig. 3.1.3.2. Mean radioactivity in air, 1957-65.

3.1.4. Bed soil from the Fjord

Fig. 3.1.3.1 shows the control chart for BI. The mean activity for BI was 174 eqv. mg KCl/3.0 g ash as compared with 255 eqv. mg KCl/3.0 g in 1964. Fig. 3.1.4.2 shows the mean levels for BI since 1957. Fig. 3.1.4.3 shows the mean levels for the other locations in the Fjord where samples of bed soil were collected in 1965.

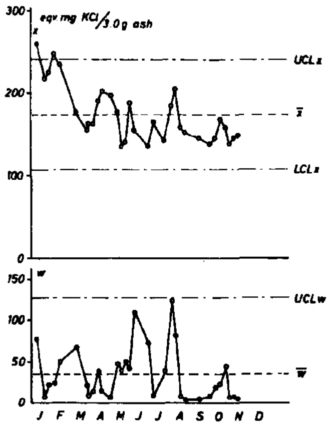

Fig. 3.1.4.1. Control chart for B I, 1965.

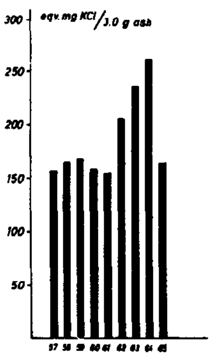

Fig. 3.1.4.2.
Mean radioactivity in bed soil, 1957-65.

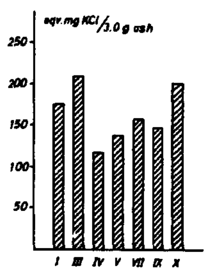

Fig. 3.1.4.3.
Gross β-activity in bed soil from the Fjord, 1965.

3.1.5. Fish

Fig. 3.1.5 shows the gross β-activity in eel meat from Roskilde Fjord measured since 1957. The mean level in 1965 was 32 eqv. mg KCl/ 5.0 g eel meat, as compared with 86 eqv. mg KCl in 1964.

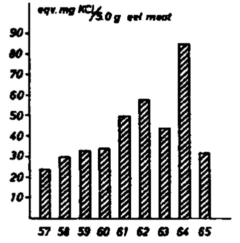

Fig. 3.1.5. Mean activity in eel meat, 1957-65.

3.1.6. Grass

The control charts are given in figs. 3.1.6.1 - 3.1.6.3. The mean values were for PG I: 42 eqv. mg KCl/0.1 g grass ash (in 1964: 222), for PG II-III: 54 eqv. mg KCl/0.1 g (in 1964: 206) and for PG IV-V: 45 eqv. mg KCl/0.1 g (in 1964: 251). Fig. 3.1.6.4 shows the mean activities in grass ash since 1957.

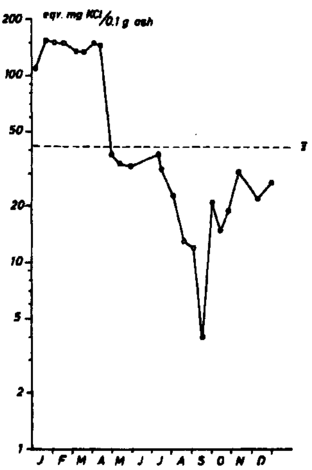

Fig. 3.1.6.1. Control chart for PG I, 1965.

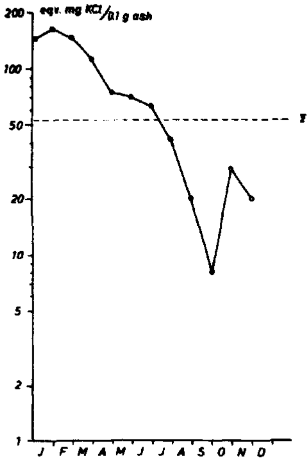

Fig. 3.1.6.3. Control chart for PG IV-V, 1965.

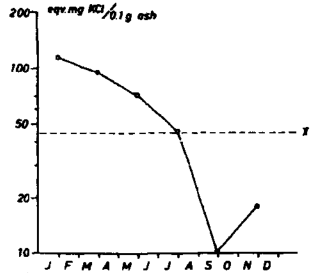

Fig. 3.1.6.2. Control chart for PG II-III, 1965.

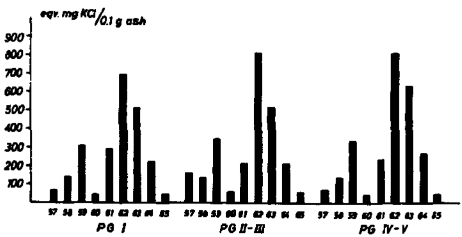

Fig. 3.1.6.4. Mean FP-radioactivity in grass ash, 1957-65.

The analysis of variance revealed no significant variations between locations (P > 70%). The variation between days was highly significant (P > 99.95%). The residual error of the grass determinations was approx. 25%.

3.1.7. Sea plants

Figs. 3.1.7.1 - 3.1.7.3 show the control sharts for PHI, PHIII and PHIX respectively. The yearly mean for Fucus vesicolosus (PHI) was 6 eqv. mg KCl/0.1 g ash (44 in 1964), and the mean FP level in Enteromorpha intestinalis (PHIII and PHIX) was 5 eqv. mg KCl/0.1 g ash (36 in 1964). Fig. 3.1.7.4 shows the mean FP radioactivity levels in sea plants since 1958.

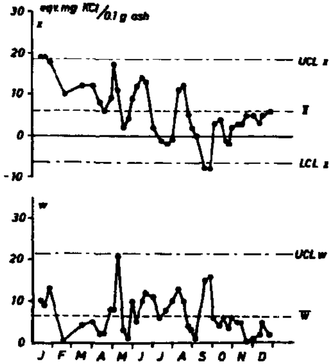

Fig. 3.1.7.1. Control chart for PH I, 1965.

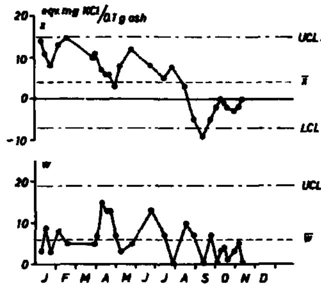

Fig. 3.1.7.2. Control chart for PH IX, 1965.

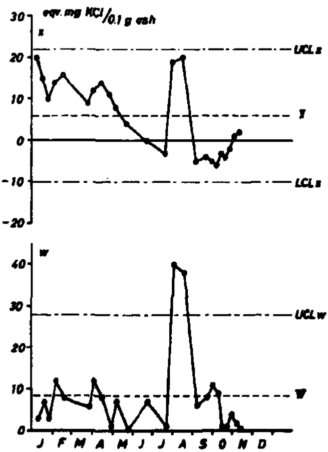

Fig. 3.1.7.3. Control chart for PH III, 1965.

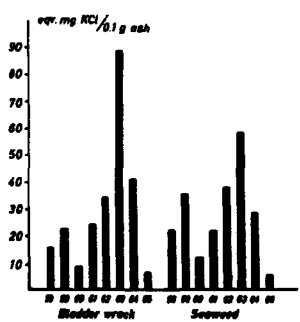

Fig. 3.1.7.4. Mean FP-activity in sea plants, 1958-65.

3.1.8. Fresh water

Figs. 3.1.8.1 - 3.1.8.4 contain the control charts for D I, D II, D IV, and S (cf. fig. 3.1.2.2). The yearly means for the four locations were 32 eqv. mg KCl/l (1964: 40), 32 eqv. mg KCl/l (1964: 47), 36 eqv. mg KCl/l (1964: 52), and 36 eqv. mg KCl/l (1964: 67) respectively. The waste water (S) did not show any indication of surplus activity in 1965. All activity in the fresh-water samples could be explained by fission-product activity from rain water.

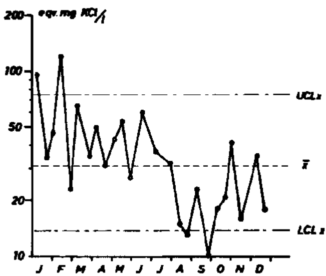

Fig. 3.1.8.1. Control chart for D I, 1965.

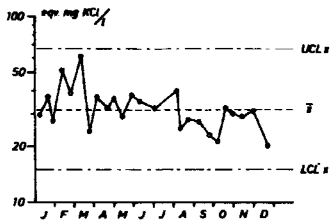

Fig. 3.1.8.2. Control chart for D II, 1965.

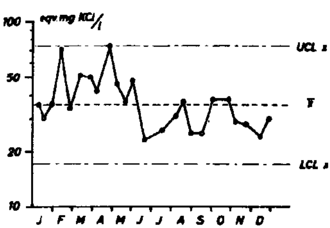

Fig. 3.1.8.3. Control chart for D IV, 1965.

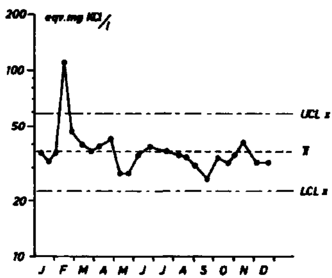

Fig. 3.1.8.4. Control chart for S, 1965.

3.1.9. Rain water

Figs. 3.1.9.1 and 3.1.9.2 show the specific FP level and the total fall-out from rain water collected daily at Risö in 1965. The total fall-out in 1965 was measured at $0.10 \cdot 10^6$ eqv. mg KCl/m^2, and the annual mean concentration in rain water at Risö was 177 eqv. mg KCl/l. In 1964 the corresponding figures were $0.56 \cdot 10^6$ and 1254 respectively.

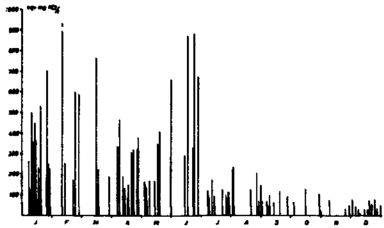

Fig. 3.1.9.1. Concentration of β-activity in rain water in 1965.

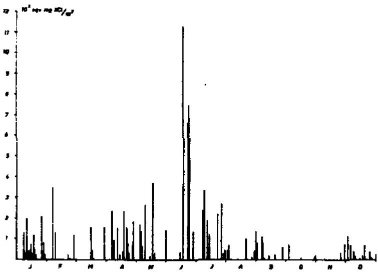

Fig. 3.1.9.2. Total fall-out from rain water in 1965.

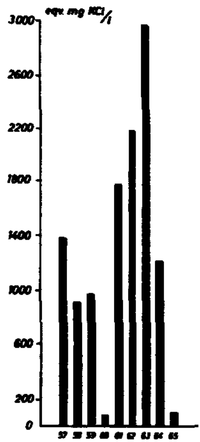

Fig. 3.1.9.3. Specific activity in precipitation, 1957-65.

Fig. 3.1.9.3 shows the specific activity in rain water since 1957.

An analysis of variance of the ln eqv. mg KCl/m^2 for the eight rain bottles - five in zone I, two in zone IV and one in zone V - (cf. figs. 3.1.2.1 and 3.1.2.2) did not prove any significant variation between locations ($P > 50\%$); the variation between months was, however, highly significant ($P > 99.95\%$). The residual error was approx. 25%.

3.1.10. Milk

Fig. 3.1.10 shows the control chart for milk from Svaleholm collected in 1965. The mean level was 950 eqv. mg KCl/l milk (in 1964: 571 eqv. mg KCl/l). The error of the total β measurements in milk is considerable because two large figures are subtracted from each other (β-

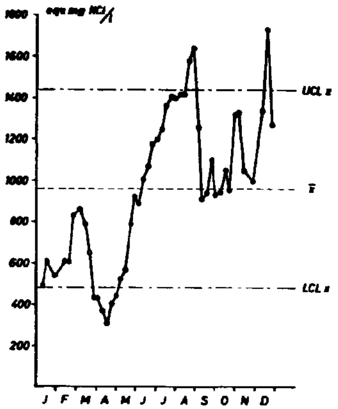

Fig. 3.1.10. Control chart for FP in M, 1965.

counting and K-determination by flame photometry), yielding a small figure. Hence we do not consider the difference between the 1964 and 1965 levels to be significant.

3.2. Radiochemical β-Analysis

3.2.1. Air

Table 3.2.1 shows the Sr-90 levels in air collected at Risö in 1965. Two collections were made, one by the daily air sampler furnished with paper filters (cf. 3.1.3) and one by the half-weekly air sampler furnished with glass-fibre filters (cf. 3.3). The daily air samples were bulked into three-monthly samples and the glass-fibre filters into monthly samples.

The mean activity level for 1965 found from the two collections was 7.2 ± 0.5 pCi Sr-90/$10^3 m^3$, i.e. a factor of 3 lower than the mean level found in 1964. The mean peak activity of the two collections in 1965 was measured in April-June to be 10.8 ± 0.1 pCi Sr-90/$10^3 m^3$, i.e. a factor of 4 lower than the peak in 1964.

Fig. 3.2.1.1 shows the Sr-90 levels in air since 1957. The Oct.-Dec. level in 1965 was 43% of the corresponding 1964 level.

Table 3.2.1

Sr-90 in Air Collected at Risö in 1965; pCi Sr-90/$10^3 m^3$

Month	Daily air samples (paper filter)	Weekly air samples (glass-fibre filter)
Jan.		7.2
Feb.	8.3	7.3
Mar.		14.7
Apr.		10.3
May	10.8	11.6
June		10.3
July		5.8*
Aug.	5.2	8.5*
Sep.		6.5*
Oct.		2.9*
Nov.	2.3	2.9*
Dec.		3.1*
Mean	6.7	7.6

*The glass-fibre filter results tabulated for the last six months of 1965 are estimated to be approx. 33% higher than the actual levels because of a modification of the sampling device in July-August.

The estimated error of the Sr-90 determinations is approx. 10%.

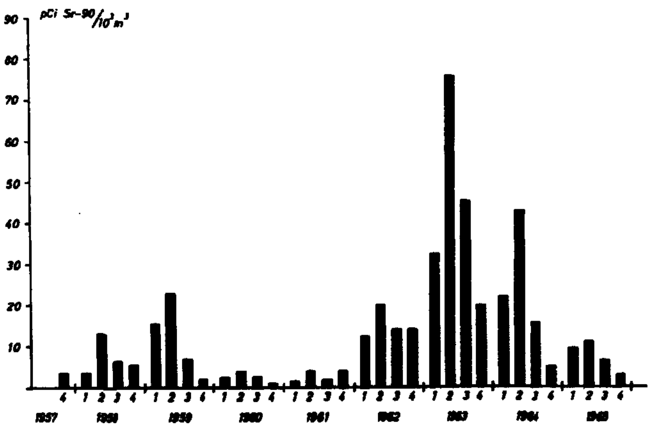

Fig. 3.2.1.1. Sr-90 in air, 1957-65.

3.2.2. Grass

Table 3.2.2 shows the Sr-90 content in grass ash from Sealand in 1965. The mean Sr-90 activity in 1965 was 13.6 pCi Sr-90/g ash or 272 S.U. as compared with 25.4 pCi/g ash or 499 S.U. in 1964, i.e. the 1965 level was approx. 54% of the 1964 level. Fig. 3.2.2.1 shows that the Sr-90 levels in grass were decreasing throughout 1965.

Table 3.2.2

Sr-90 in Grass from Sealand, 1965

	pCi Sr-90/g ash	pCi Sr-90/g Ca
Jan.-Feb.-Mar.	22.4	506.0
Apr.-May-June	15.0	303.0
July-Aug.-Sept.	8.6	139.1
Oct.-Nov.-Dec.	8.5	138.1
Mean	13.6	271.6
The estimated error of the determinations is approx. 10%.		

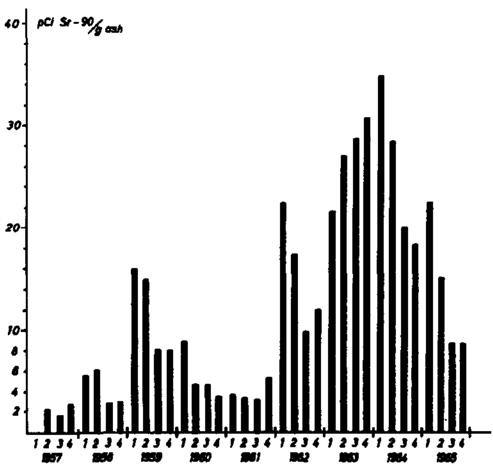

Fig. 3.2.2.1. Sr-90 in grass ash, 1957-65.

3.2.3. Sea plants

Table 3.2.3 shows the Sr-90 content in sea plants collected from Roskilde Fjord in 1965.

The mean level in Fucus vesicolosus was 36 S.U. in 1965 as compared with 21 S.U. in 1964, and in Enteromorpha intestinalis the 1965 mean content was 17 S.U. as compared with 18 S.U. in 1964.

Fig. 3.2.3 shows the S.U. levels in sea plants since 1959. It is evident that Fucus vesicolosus contains more Sr-90 per g calcium than Enteromorpha intestinalis, and that the 1965 figures for Fucus vesicolosus are the highest found since the measurements began.

Table 3.2.3

Sr-90 in Sea Plants from Roskilde Fjord in 1965

Sampling period	Location	Species	pCi Sr-90/g Ca	pCi Sr-90/g ash
Jan.-June	PH I	Fucus vesicolosus	37.4	3.74
Jan.-June	PH III-IX	Enteromorpha intestinalis	25.1	1.10
July-Dec.	PH I	Fucus vesicolosus	33.8	4.37
July-Dec.	PH III-IX	Enteromorpha intestinalis	9.1	0.49
The estimated error of the results is approx. 15%.				

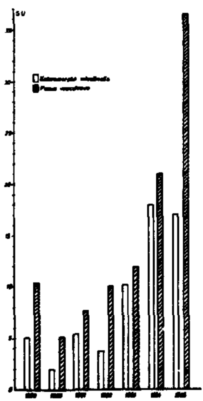

Fig. 3.2.3. Sr-90 in sea plants, 1959-65.

3. 2. 4. Rain water

Table 3. 2. 4. 1 shows the radiostrontium level in rain water collected at Risö 1965. The total Sr-90 fall-out in 1965 was 4. 07 mCi Sr-90/km^2 (688 mm precipitation), and the mean concentration in the rain water was 5. 9 pCi Sr-90/l. In 1964 we measured 11. 5 mCi Sr-90/km^2 (542 mm precipitation) and 20. 8 pCi Sr-90/l, i. e. the specific activity decreased from 1964 to 1965 by a factor of 3. 5 and the fall-out by a factor of 2. 8.

Fig. 3. 2. 4. 1 shows the Sr-90 levels in rain water since 1959. As for air and grass, the Sr-90 activity in rain decreased rapidly during the last months of the year.

At five sampling locations (1-5) in zone I (cf. fig. 3. 1. 2. 1) ion-exchange columns collected monthly samples of precipitation along with the bottle collectors. The columns have been described earlier[6)] and are similar to those used in the U. S. A. by HASL[12)]. The purpose of this collection was to compare the efficiency of the ion-exchange columns with that of rain bottles as collectors of fall-out. Table 3. 2. 4. 2 shows the results, and table 3. 2. 4. 4 gives the analysis of variance of the fall-out measured by means of bottles and ion-exchange columns. It is evident that the two methods yielded identical results within the error of measurement.

Table 3. 2. 4. 1

Sr-90 in Monthly Samples of Rain Water Collected in Rain Bottles at Risö in 1965 (sampling area 1232 cm^2)

Month	mm precipitation	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	55. 3	6. 6	0. 36
Feb.	12. 6	11. 8	0. 15
Mar.	19. 0	11. 0	0. 21
Apr.	61. 9	8. 9	0. 55
May	59. 1	11. 1	0. 66
June	48. 6	13. 9	0. 68
July	131. 5	5. 2	0. 68
Aug.	36. 7	6. 0	0. 22
Sept.	61. 3	3. 9	0. 24
Oct.	53. 0	2. 3	0. 12
Nov.	24. 1	3. 7	0. 09
Dec.	125. 3	0. 9	0. 11
1965	Σ 688	$\bar{x}$ 6. 9	Σ 4. 07
The estimated error of the Sr-90 determinations is 10-15%.			

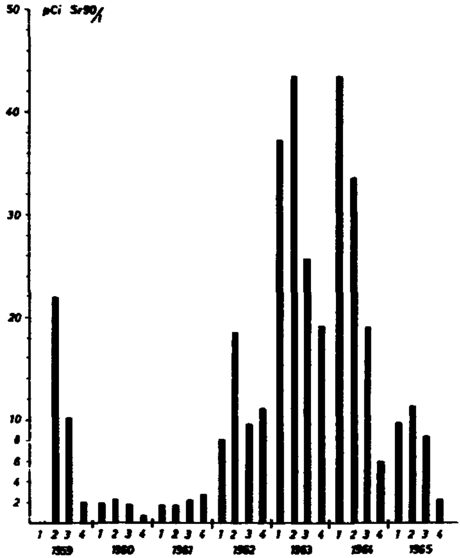

Fig. 3.2.4. Sr-90 in precipitation, 1959-65.

<u>Table 3.2.4.2</u>

Sr-90 in Monthly Samples of Rain Water Collected in Ion-Exchange Column Collectors at Risø in 1965 (sampling area 2450 cm^2)

Month	mm precipitation	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	39.4	7.4	0.29
Feb.	12.4	8.8	0.11
Mar.	23.8	8.0	0.19
Apr.	96.4	5.6	0.54
May	70.3	11.0	0.77
June	69.4	11.1	0.77
July	73.3	7.9	0.58
Aug.	38.3	5.5	0.21
Sep.	68.8	3.2	0.22
Oct.	53.8	1.3	0.07
Nov.	66.6	2.1	0.14
Dec.	92.3	2.0	0.18
1965	Σ 705	$\bar{x}$ 5.8	Σ 4.07
The estimated error of the Sr-90 determinations is approx. 15%.			

Table 3.2.4.3

Sr-90 in Monthly Samples of Rain Water Collected Daily in a 1 m^2 Rain Collector at Risö in 1965

Month	mm precipitation	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	33.8	7.81	0.26
Feb.	12.5	32.80	0.41
Mar.	13.3	30.70	0.41
Apr.	51.0	7.97	0.41
May	54.0	7.32	0.40
June	36.7	18.90	0.69
July	130.5	(5.2)^x	(0.68)^x
Aug.	25.0	7.59	0.19
Sept.	53.8	2.64	0.14
Oct.	21.8	4.41	0.10
Nov.	39.0	3.36	0.13
Dec.	91.5	2.85	0.26
1965	Σ 563	$\bar{x}$ 7.24	Σ 4.08

^{x} Estimated figures

The estimated error of the Sr-90 determinations is approx. 20%.

Table 3.2.4.4

Analysis of Variance of ln mCi Sr-90/km^2 Measured by Rain Bottles and by Ion-Exchange Columns in 1965 at Risö (from tables 3.2.4.1 and 3.2.4.2)

Variation	n/24 SSD	f	s^2	v^2	P
Between methods	0.0024	1	0.0024	0.06	-
Between months	12.4426	11	1.1311	25.94	> 99.95%
Remainder	0.4796	11	0.0436		
Total	12.9246	23			
η = 0.21					

Table 3.2.4.3 shows Sr-90 determined in monthly samples of rain water collected daily in the 1 m^2 rain collector (R) (cf. fig. 3.1.2.1) at Risö. The monthly samples were subjected to ion exchange in the laboratory on a column similar to those used in the field sampling described above; the rain was then γ-counted for Cs-137 (cf. table 3.3.2) and analysed for Sr-90.

The total Sr-90 fall-out determined for 1965 by this method is identical with that found by the other two methods mentioned in this section; however, the amount of precipitation was only approx. 80% of that measured by the other two methods, and consequently the specific activity was greater by a factor of 1.2 in the samples from the 1 m^2 collector.

3.2.5. Milk from Svaleholm

Table 3.2.5 shows the radiostrontium content in milk collected in 1965 from Svaleholm at Risö. The mean level was 12.5 S.U. as compared with 16.6 S.U. in 1964. Fig. 3.2.5 shows the Sr-90 levels in Svaleholm milk since 1959. The maximum level in 1965 was measured in January-March.

Table 3.2.5

Sr-90 in Milk from Svaleholm, 1965

Month	pCi Sr-90/g Ca
Jan.-Mar.	13.9
Apr.-June	11.8
July-Sep.	11.1
Oct.-Dec.	13.3 ± 1.1
Mean	12.5
The estimated error of the determinations is approx. 10%.	

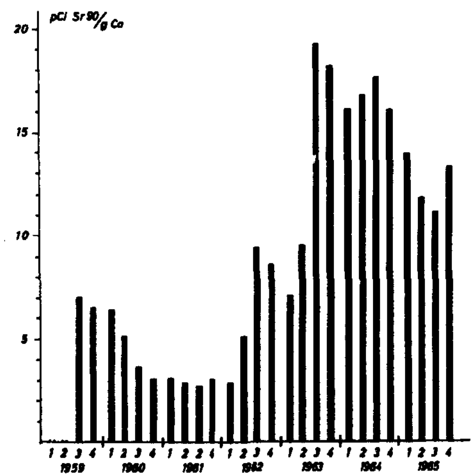

Fig. 3.2.5. Sr-90 in milk from Svaleholm, 1959-65.

3.3. γ-Spectroscopy of Air and Precipitation Samples

As in 1962-64, half-weekly samples of air were collected by means of the air sampler described in Risö Report No. 23[5]. Parts of the weekly filters were bulked into monthly samples, each representing approx. 70,000 m^3 air. The filters were measured by γ-spectrometry.

Mn-54, Zr-95 and Cs-137 were determined in the filters by subtraction of known standards from the filter spectra on the TMC pulse-height analyser. Table 3.3.1 shows the results and fig. 3.3.1 the isotope ratios Zr-95/Cs-137 and Mn-54/Cs-137.

The Zr-95/Cs-137 ratios were below the limit of detection in most of 1965, but in June a marked increase due to the second Chinese nuclear explosion on May 14th, was observed. As shown in fig. 3.3.2, the main cloud from this explosion did not appear in ground-level air till approx. one month after the explosion, i.e. 1-2 weeks later than that from the first Chinese explosion in October 1964[9].

The Mn-54/Cs-137 ratios were rather constant during the first half of 1965, but decreased markedly in the last few months of the year.

Table 3.3.2 shows the monthly levels of Cs-137 collected daily in the 1 m^2 rain collector at Risö (cf. 3.2.4). The Cs-137/Sr-90 ratio in rain in May-December 1965 was calculated at $\frac{3.96}{2.59} = 1.52$.

Table 3.3.1

γ-Measurements of Monthly Air Filters (Glass Fibre) Employed at Risö in 1965

Month	Cs-137 $pCi/10^3\ m^3$	Mn-54 $pCi/10^3\ m^3$	Zr-95 $pCi/10^3\ m^3$	Be-7 $pCi/10^3\ m^3$
Jan.	8.2	2.2	0.4	-
Feb.	8.9	2.5	0.4	-
Mar.	14.4	3.9	-	-
Apr.	15.9	3.9	-	-
May	23.2	6.0	-	-
June	15.1	2.9	11.9	-
July	10.0	2.7	1.8	98
Aug.	8.4	2.3	-	49
Sept.	7.1	0.8	-	68
Oct.	6.0 (7.3)	0.8	-	67 (69)
Nov.	4.6 (4.7)	0.8 (0.6)	-	54 (38)
Dec.	2.1 (2.6)	0.4 (0.3)	-	32 (30)

The figures in brackets are determinations on paper filters.
The estimated error of the γ-Measurements is approx. 15%.

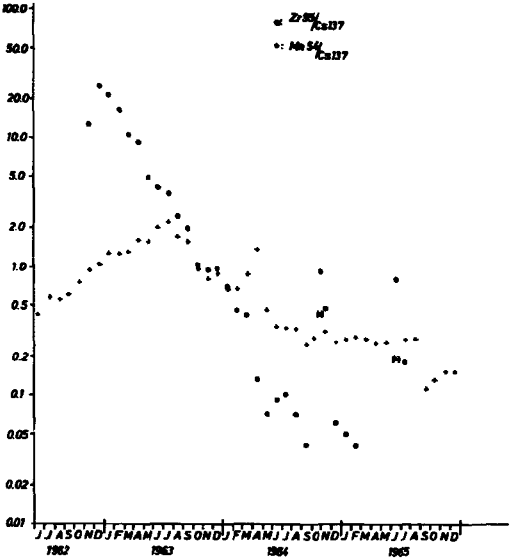

Fig. 3.3.1. Isotope ratios in air in 1962-65.

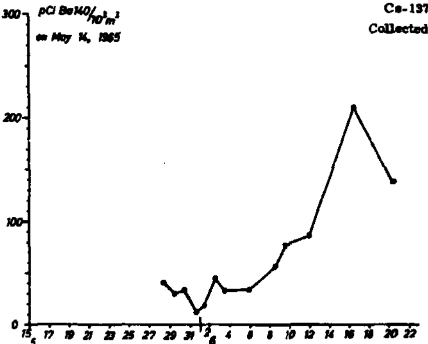

Fig. 3.3.2. Ba-140 in ground-level air collected at Risö in the period 15/5-21/6, 1965.

Table 3.3.2

Cs-137 in Monthly Ion-Exchange Resin Samples of Rain Water Collected Daily in a 1 m^2 Rain Collector at Risö in May-Dec. 1965

Month	mm precipitation	pCi Cs-137/l	mCi Cs-137/km^2
May	54.0	11.7	0.63
June	36.7	9.8	0.36
July	130.5	5.2	0.67
Aug.	25.0	18.6	0.46
Sep.	53.8	8.1	0.43
Oct.	21.8	15.9	0.35
Nov.	39.0	7.0	0.27
Dec.	91.5	8.6	0.79
1965	Σ 452	$\bar{\bar{x}}$ 8.8	Σ 3.96

The estimated error of the Cs-137 determinations is approx. 15%.

4. RADIOSTRONTIUM IN PRECIPITATION, SOIL AND GROUND WATER IN DENMARK IN 1965

4.1. Precipitation

Samples of rain water were collected in 1965 from the ten state experimental farms (cf. 4.1.1) according to the principles laid down in Risö Report No. 63, p. 51[7].

Table 4.1.1 shows the results of the Sr-90 determinations and tables 4.1.2 and 4.1.3 the analysis of variance of the results. The variation with time was highly significant ($P > 99.95\%$). The maximum specific activity occurred in May-June, when the mean content in precipitation was 12.6 pCi Sr-90/l. The maximum fall-out rate occurred in May-June with a mean fall-out rate in this period of 1.17 mCi Sr-90/km^2. Table 4.1.2 shows that the variation in specific activity between locations was not significant, whereas according to table 4.1.3 there was a significant variation between locations as regards the fall-out rate. The fall-out rate for 1965 was thus 4.84

Sr-90

Period	Unit	Tylstrup	Studsgård	Ødum	Askov
Jan.-Feb.	pCi/l	8.02	6.58	11.10	8.03
	mCi/km^2	0.44	0.66	0.60	0.88
Mar.-Apr.	pCi/l	11.00	7.80	9.90	9.33
	mCi/km^2	0.77	0.68	0.72	0.96
May-June	pCi/l	16.70	12.90	16.30	11.30
	mCi/km^2	1.43	1.27	1.03	1.12
July-Aug.	pCi/l	4.93	4.50	4.72	4.76
	mCi/km^2	0.72	0.89	0.63	1.08
Sep.-Oct.	pCi/l	3.19	3.14	2.84	3.91
	mCi/km^2	0.29	0.46	0.22	0.50
Nov.-Dec.	pCi/l	1.83	1.58	2.04	1.57
	mCi/km^2	0.30	0.23	0.23	0.30
1965	$\bar{x}$ pCi/l	7.61	6.08	7.81	6.48
	Σ mCi/km^2	3.95	4.19	3.43	4.84
mm precipitation in 1965 Σ		519	689	439	747

x) The Sr-90 mean level in precipitation in the year 1965 was calculated at $\frac{3.95}{0.597}$.
The coefficient of variation of the results was approx. 20%.
Brackets indicate that the sample was lost and the figures calculated by the method of least squares.

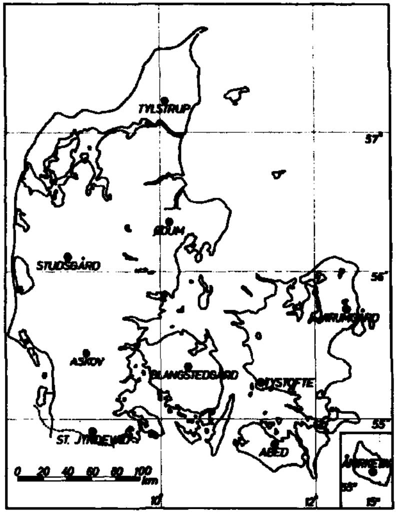

Fig. 4.1.1. State experimental farms in Denmark.

Table 4.1.1

Fall-out in Denmark in 1965

St. Jyndevad	Blangstedgård	Tystofte	Virumgård	Abed	Åkirkeby	Mean
(7.17) (0.77)	8.98 0.73	6.04 0.33	6.00 0.33	8.70 0.51	8.28 0.37	7.69 0.56
9.10 0.79	7.60 0.60	9.50 0.73	13.40 0.84	10.00 0.72	13.80 0.65	10.14 0.76
13.60 1.36	9.28 0.93	11.80 1.17	9.82 0.90	13.00 1.11	10.80 1.47	12.55 1.17
4.38 0.94	4.17 0.79	5.20 0.69	4.35 0.62	5.50 1.01	6.79 1.13	4.93 0.85
2.94 0.46	3.94 0.30	3.17 0.25	2.90 0.28	3.04 0.26	2.72 0.30	3.17 0.33
1.37 0.27	1.50 0.26	1.70 0.20	1.65 0.21	2.48 0.36	1.96 0.37	1.77 0.27
6.43 4.61	5.90 3.61	6.24 3.37	6.35 3.26	7.12 3.97	7.39 4.29	6.67[x)] 3.95
717	612	540	517	556	581	592

Table 4.1.2

Analysis of Variance of ln pCi Sr-90/l Precipitation in 1965
(from table 4.1.1)

Variation	n/60 SSD	f	s^2	v^2	P
Between locations	0.3996	9	0.0444	1.56	70-90%
Between months	27.7567	5	5.5513	194.78	> 99.95%
Remainder	1.2521	44	0.0285		
Total	29.4084	58			
η = 0.17					

Table 4.1.3

Analysis of Variance of ln mCi Sr-90/km^2 in 1965
(from table 4.1.1)

Variation	n/60 SSD	f	s^2	v^2	P
Between locations	1.2033	9	0.1337	2.92	> 99%
Between months	16.3382	5	3.2676	71.34	> 99.95%
Remainder	2.0135	44	0.0458		
Total	19.5550	58			
η = 0.22					

Sr-90 in Soil Collected on the State

	Tylstrup	Studsgård	Ødum$^{x)}$	Askov	St. Jyndevad
mCi Sr-90/km^2	58.7 $\pm$ 1.7	66.3 $\pm$ 2.7	46.2 $\pm$ 3.1	70.0 $\pm$ 3.1	81.1 $\pm$ 1.4
pCi Sr-90/kg	272 $\pm$ 8	268 $\pm$ 10	184 $\pm$ 12	238 $\pm$ 6	224 $\pm$ 6

x) Double determinations x) single determination. The error term is otherwise mCi Sr-90/km^2 at Askov, while only 3.28 mCi Sr-90/km^2 was measured at Virumgård. The 1965 mean levels for the ten state experimental farms were 3.95 mCi Sr-90/km^2 and 6.67 pCi Sr-90/l. In Appendix A the country mean level (area weighted) is estimated to be 4.8 mCi Sr-90/km^2 for a mean precipitation amount of 714 mm (area weighted), i.e. approx. 42% of the fall-out rate in 1964.

4.2. Soil

As in the previous years[5-9], soil was collected with a view to estimating the accumulated fall-out of Sr-90. As in 1964[9], the samples were collected in September from uncultivated soil (cf. fig. 4.1.1) all over the country.

Table 4.2.1 shows the results from the ten state experimental farms. The mean value in September 1965 was 54.7 mCi Sr-90/km^2 (S.D. = 9, S.E. = 2.8). The mean increase of accumulated Sr-90 in Danish soil from September 1964 to September 1965 was approx. 3 mCi Sr-90/km^2 [8]. From table 4.1.1 and from ref. 9) the mean fall-out in this period was estimated to be approx. 5.3 mCi Sr-90/km^2, while the decay of the accumulated Sr-90 from 1964 to 1965 was 1.3 mCi Sr-90/km^2.

The mean fall-out at the ten state experimental farms was estimated to be 55.3 mCi Sr-90/km^2 by the end of 1965.

In September 1965 the mean level at the state experimental farms in Jutland was 23% higher than that at the five farms in eastern Denmark.

Table 4.2.2 shows the Sr-90 levels at four soil locations in Sealand, mainly in the neighbourhood of Risö.

Table 4.2.1

Experimental Farms in September 1965

Blangstedgård$^{x)}$	Tystofte	Virumgård	Abed$^{x)}$	Åkirkeby	Mean	S.D.	S.E.
44.7	46.3 $\pm$ 1.4	55.1 $\pm$ 2.2	48.5	50.5 $\pm$ 2.0	54.7	9.0	2.8
188	164 $\pm$ 5	212 $\pm$ 8	304	195 $\pm$ 8	225	45	14

the S.E. of triple determinations.

Table 4. 2. 2

Sr-90 in Soil Collected in Sealand in September 1965

	Risö x)	Eremitagen	Roskilde Fælled	Ledreborg	Mean	S.D.	S.E.
mCi Sr-90/km^2	46.8 $\pm$ 2.8	56.5 $\pm$ 3.4	49.4 $\pm$ 1.4	38.9 $\pm$ 4.7	47.9	7.3	3.7
pCi Sr-90/kg	216 $\pm$ 17	238 $\pm$ 14	197 $\pm$ 7	134 $\pm$ 15	196	45	22

The error term is the S.E. of triple determinations.

x) Risö represents samples from two locations near Risö: Bolund and Veddelev, and the error term in this case is the S.E. of the mean of six analyses.

4.3. Ground Water

As in 1964, ground water was collected in March from the nine locations selected by L. J Andersen, M. Sc., Geological Survey of Denmark, in 1961[6].

To obtain a better counting of the samples, 100 l water was processed for an analysis instead of only 50 l as previously.

Fig. 4.3 shows the sample locations and table 4.3 the results of the Sr-90 analyses (cf. also 5.8.4).

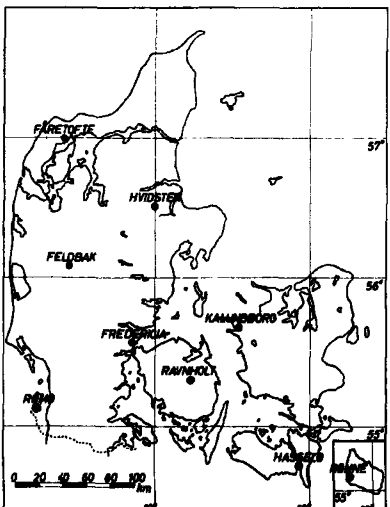

Fig. 4.3. Ground-water locations in Denmark.

Table 4. 3. 1

Sr-90 in Ground Water Collected in March 1965

Location	pCi Sr-90/l	pCi Sr-90/g Ca	mg Sr/g Ca
Hvidsten	0.003	0.041	5.4
Feldbak	0.094	4.580	9.8
Rømø	0.020	0.470	8.7
Rønne	0.018	1.290	3.9
Hasselø	0.006	0.041	5.3
Fåretofte	0.031	0.230	2.6
Kalundborg	0.031	0.305	7.3
Ravnholt	0.019	0.148	8.3
Fredericia	0.064	0.354	8.3
Mean	0.032	-	6.6
S.D.	0.029	-	2.4
The relative error of the determinations was estimated at approx. 25%.			

Table 4. 3. 2

Analysis of Variance of ln pCi Sr-90/m^3 Ground Water, 1961, 1963-65
(from table 4. 3. 1 and refs. 6, 8 and 9)

Variation	n/36 SSD	f	s^2	v^2	P
Between locations	7.6733	8	0.9592	2.31	~ 95%
Between years	9.3427	3	3.1142	7.49	>99.5%
Remainder	9.9858	24	0.4160		
Total	27.0018				
η = 0.70					

Table 4. 3. 2 shows an analysis of variance of the Sr-90 levels in ground water sampled in 1961, 1963, 1964, and 1965 at the nine locations shown in fig. 4. 3. The variation between locations was probably significant (P ~ 95%). Thus Feldbak showed higher levels than most other locations in all the years, whereas Hvidsten was among the locations with the lowest activity. This is in agreement with the fact that the filtering strata at Feldbak are very poor, consisting of sand, while at Hvidsten the rain is filtered through varying strata of sand and clay. The variation between years is significant. The levels in 1961 and 1965 were lower than those measured in 1963 and 1964. This indicates that the variations of Sr-90 in the precipitation are rather rapidly reflected in the Sr-90 concentrations found in ground water, although there seems to be a buffer effect which makes the variations in the ground-water levels less pronounced than those observed in the precipitation.

5. RADIOSTRONTIUM AND RADIOCAESIUM IN DANISH FOOD IN 1965

5.1. Sr-90 and Cs-137 in Dried Milk from the Entire Country

As in the previous years[7], monthly samples of dried milk were collected from seven dried-milk factories in Denmark (cf. fig. 5.1.1) and analysed for Sr-90 and Cs-137.

Table 5.1.1 shows the results of the Sr-90 determinations and table 5.1.2 the analysis of variance of the results. The maximum of the year was reached by 21.4 S.U. in February. The S.U. mean level in 1965 was 17.4 pCi Sr-90/g Ca or 70% of the 1964 mean.

As in the previous years, the milk from East Denmark shows significantly lower levels than that from Jutland.

Table 5.1.3 shows the results of the Cs-137 determinations and table 5.1.4 the analysis of variance of the results. As in the previous years, the maximum level of Cs-137 (47 M.U., i.e. 44% of the maximum measured in 1964) was found in milk from the summer months (June-July). The M.U. mean level in 1965 was 33 pCi Cs-137/g K or 49% of the Cs-137 mean content found in 1964. The variation between locations was a little less pronounced in 1965 than in 1962-64.

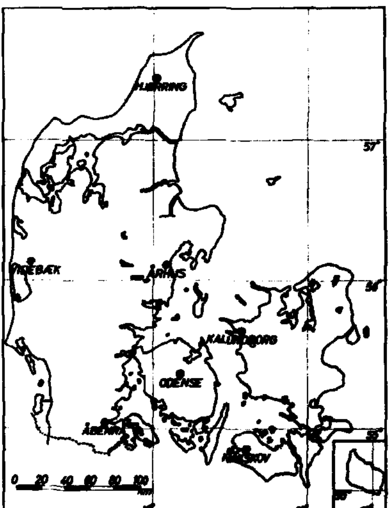

Fig. 5.1.1. Dried-milk factories in Denmark.

Table 5.1.1

Sr-90 in Danish Dried Milk, 1965

pCi Sr-90/g Ca

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Kalundborg	Nakskov	Mean
Jan.	27.1	23.4	26.6	23.9	15.6	14.2	12.9	20.5
Feb.	26.8	22.1	28.2	24.8	16.3	17.1	14.2	21.4
Mar.	28.8	22.4	26.4	24.3	17.3	17.3	13.4	21.3
Apr.	28.6	20.8	25.6	23.6	15.2	13.7	11.8	19.9
May	25.7	18.1	28.3	24.3	12.9	12.9	10.6	19.0
June	22.6	13.8	21.2	18.2	13.3	9.7	8.8	15.3
July	16.8	17.4	25.6	17.4	12.7	9.3	8.2	15.3
Aug.	17.3	13.8	17.2	16.3	12.9	8.9	9.6	13.7
Sep.	13.1	12.5	17.4	14.8	13.3	8.5	8.0	12.4
Oct.	17.4	15.1	19.4	18.2	15.5	8.5	8.8	14.7
Nov.	20.6	18.2	22.8	26.0	12.6	12.8	11.6	17.5
Dec.	22.3	16.2	22.6	24.3	15.8	12.4	9.2	17.5
Mean	22.3	17.8	23.4	21.2	14.4	12.1	10.5	17.4

As 1 litre of milk contains 1.2 g Ca the mean Sr-90 content in Danish milk produced in 1965 was 20.8 pCi/l. The coefficient of variation of the results was 10%.

Table 5.1.2

Analysis of Variance of ln S.U. in Dried Milk in 1965

(from table 5.1.1)

Variation	n/84 SSD	f	s^2	v^2	P
Between locations	7.2269	6	1.2045	116.94	> 99.95%
Between months	2.5691	11	0.2336	22.68	> 99.95%
Remainder	0.6823	66	0.0103		
Total	10.4783	83			
η = 0.10					

Table 5.1.3

Cs-137 in Danish Dried Milk in 1965, pCi Cs-137/g K

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Kalundborg	Nakskov	Mean
Jan.	55	46	43	42	35	20	18	37
Feb.	65	39	61	40	30	23	20	40
Mar.	60	33	62	39	27	24	23	38
Apr.	61	35	54	34	25	28	19	37
May	51	35	50	29	21	26	25	34
June	66	59	70	45	47	22	23	47
July	67	45	73	57	30	25	29	47
Aug.	44	32	47	33	27	20	17	31
Sep.	34	29	45	37	32	19	18	30
Oct.	25	24	39	31	25	11	10	23
Nov.	27	19	32	27	13	9	12	21
Dec.	28	10	23	23	18	9	10	17
Mean	49	34	50	36	28	20	19	33

As 1 litre of milk contains approx. 1.66 g K, the mean Cs-137 content in Danish milk produced in 1965 was estimated at 55 pCi Cs-137/l. The coefficient of variation of the results was 17%.

Table 5.1.4

Analysis of Variance of ln M.U. in Dried Milk in 1965 (from table 5.1.3)

Variation	n/84 SSD	f	s^2	v^2	P
Between locations	11.2608	6	1.8768	66.55	> 99.95%
Between months	6.7439	11	0.6130	21.74	> 99.95%
Remainder	1.8618	66	0.0282		
Total	19.8665	83			
η = 0.17					

Figs. 5.1.2 and 5.1.3 show the quarterly S.U. and M.U. values since October-December 1959. The quarterly maximum in 1965 for Sr-90 was reached in January-March by 21.1 S.U. and for Cs-137 in April-June by 39 M.U. (~65 pCi Cs-137/l).

An analysis of variance of the M.U./S.U. ratios in 1965 shows a highly significant variation both between locations and between months (P > 99.9%). The ratios were thus significantly lower in the samples from Kalundborg (annual mean ratio = 1.7) than in those from Hjørring (annual mean ratio = 2.2), cf. fig. 5.1.4. The variation with time is given in fig.

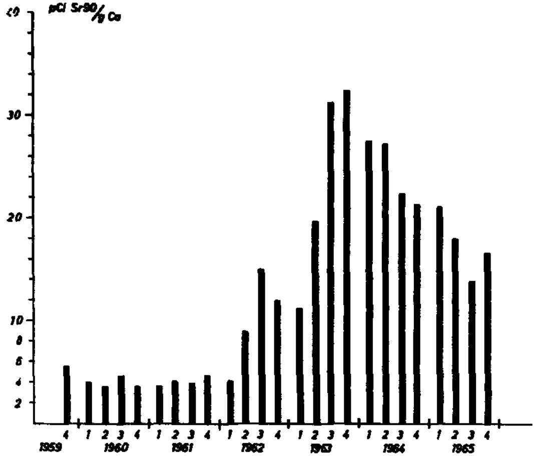

Fig. 5.1.2. Sr-90 in dried milk, 1959-65.

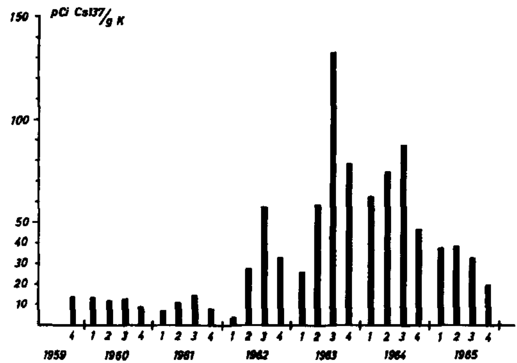

Fig. 5.1.3. Cs-137 in dried milk, 1959-65.

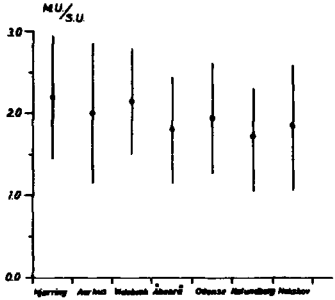

Fig. 5.1.4. Yearly means from different locations of M. U. /S. U. ratios in dried milk in 1965 (1. S. D. indicated).

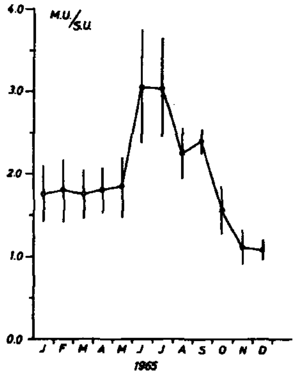

Fig. 5.1.5. Monthly means of M. U. /S. U. ratios in dried milk in 1965 (1. S. D. indicated).

5.1.5, which shows that the ratios were three times greater in the summer than in the winter.

It is remarkable that the M. U. /S. U. mean ratio in milk in 1965 was only approx. 70% of that found in 1964. It agrees with the fact that the decreasing fall-out rate (and the increasing amount of accumulated fall-out in the soil) diminish the uptake of Cs-137 by the grass relatively more than the uptake of Sr-90 on pastures where the root uptake of Cs-137 is negligible, as is the case in Denmark.

5.2. Sr-90 and Cs-137 in Fresh Milk from the Entire Country

The samples of fresh milk were collected in the eight zones and in Copenhagen as in 1964 (cf. figs. 5.2.1 and 5.2.2), but only in June and December along with the total-diet collection (cf. 5.7).

Table 5.2.1 shows the results of the determinations of radiostrontium in consumers' milk and table 5.2.2 the analysis of variance of the S.U. zone figures. The variations with location as well as those with time were significant. Thus the S.U. levels in Jutland were greater by nearly a factor of two than those in East Denmark, and the mean S.U. level in December was 15% higher than the level found in June.

This is in agreement with the observations made for dried milk (cf. 5.1), and it might be an indication of a higher S.U. level in the winter diet than in the summer diet of the cows in 1965, probably due to the fact that turnips and beets, which are used in the winter fodder, have a higher root uptake of Sr-90 than grass. Another explanation might be that the calcium intake of the cows is smaller in winter than in summer.

Table 5.2.3 shows the results of the Cs-137 determinations and table 5.2.4 the analysis of variance of the results. As was the case with

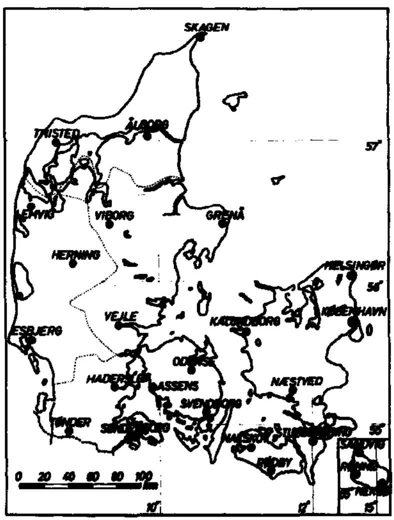

Fig. 5.2.1. Sample locations for fresh milk, bread, total diet, and drinking water (A-towns).

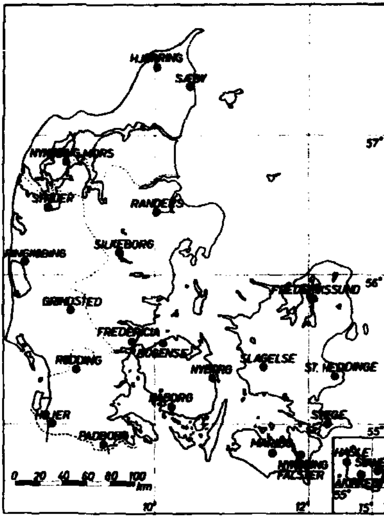

Fig. 5.2.2. Sample locations for fresh milk, bread, total diet, and drinking water (B-towns).

Table 5.2.1

Sr-90 in Fresh Milk in 1965

Zone	June S.U.	Dec. S.U.	Mean S.U.
I	18.8	19.5	19.2
II	15.6	16.5	16.1
III	17.7	20.7	19.2
IV	19.4	22.6	21.0
V	9.4	12.4	10.9
VI	9.0	13.5	11.3
VII	10.8	11.1	11.0
VIII	10.3	12.9	11.6
Mean	13.9	16.2	15.0
Copenhagen	9.5	11.9	10.7
Population-weighted mean	12.9	15.3	14.1
Production-weighted mean	14.9	17.1	16.0
The coefficient of variation of the results is 9%.			

Table 5.2.2

Analysis of Variance of ln S.U. in Milk from the Zones in 1965
(from table 5.2.1)

Variation	n/16 SSD	f	s^2	v^2	P
Between locations	1.1833	7	0.1690	19.65	> 99.95%
Between months	0.1122	1	0.1122	13.05	> 99%
Remainder	0.0600	7	0.0086		
Total	1.3555	15			
η = 0.09					

Table 5.2.3

Cs-137 in Fresh Milk in 1965

Zone	June M.U.	Dec. M.U.	Mean M.U.	June pCi/l	Dec. pCi/l	Mean pCi/l
I	95	34	65	152	50	101
II	43	22	33	84	41	63
III	42	19	31	70	34	52
IV	46	25	36	86	49	68
V	20	19	20	33	37	35
VI	23	10	17	44	15	30
VII	24	12	18	37	24	31
VIII	29	10	20	51	20	36
Mean	40	19	30	70	34	52
Copenhagen	27	16	22	51	31	41
Population-weighted mean	38	18	28	68	34	51
Production-weighted mean	47	21	34	81	37	59
The coefficient of variation of the results is 22%.						

Table 5.2.4

Analysis of Variance of ln M.U. in Milk from the Zones in 1965
(from table 5.2.3)

Variation	n/16 SSD	f	s^2	v^2	P
Between locations	2.8679	7	0.4097	8.40	> 99%
Between months	2.0808	1	2.0808	42.64	>99.95%
Remainder	0.3420	7	0.0488		
Total	5.2907	15			
η = 0.22					

Sr-90, the variations between both locations and sampling months were significant.

The production-weighted means for Sr-90 and Cs-137 in Danish consumers' milk in 1965 were 16.0 S.U. (= 19.2 pCi Sr-90/l) and 34 M.U. or 59 pCi Cs-137/l respectively, i.e. approx. 65% of those found in 1964 (S.U. figures) and approx. 50% if M.U figures are considered.

It seems reasonable to regard the mean of the levels found in June and December as representative of the annual production-weighted mean, as the mean for these two months calculated from the dried-milk data (cf. tables 5.1.1 and 5.1.2) fitted the annual mean for dried milk to within 10% for S.U. and 3% for M.U.

If the figures in tables 5.2.1 and 5.2.3 are weighted with respect to the population, the country means become 14.1 S.U. and 51 pCi Cs-137/l, i.e. 85-90% of the production-weighted means. This is in agreement with the observations of earlier years.

5.3. Sr-90 and Cs-137 in Grain from the Entire Country

As in the previous years, grain samples were obtained from the ten state experimental farms (cf. fig. 4.1.1). Sr-90 and Cs-137 were determined in fresh samples as before[7].

Table 5.3.1 shows the measurements of strontium 90 in grain in 1965. According to Appendix B, approx. 3/4 of all rye in Denmark is grown in Jutland and 1/4 in the eastern part of the country. As regards wheat, 2/3 is produced in eastern Denmark and 1/3 in Jutland. In the calculation of the means in tables 5.3.1 and 5.3.4 Jutland is represented by six rye figures and eight wheat figures, while eastern Denmark contributes nine wheat figures and only five rye figures. Thus the rye-grain means in table 5.3.1 and 5.3.4 are probably a little smaller than the production-weighted means for the country because Jutland shows higher activity levels than eastern Denmark, whereas the opposite is the case with the wheat-grain means in the two tables. Table 5.3.2 gives the analysis of variance of the S.U. figures and table 5.3.3 that of the pCi Sr-90/kg grain figures.

As in previous years, the variation with location was highly significant; the mean pCi Sr-90/kg level for grain from Jutland was approx. 1.4 times that in eastern Denmark, i.e. the difference between locations was not so pronounced as in the previous years.

It is remarkable that it was not possible to prove any significant difference between species as regards pCi Sr-90/kg levels (cf. table 5.3.3) in 1965 (although rye still showed a higher average level than the other

Table 5.3.1

Strontium-90 in Grain in 1965

	Rye		Barley		Wheat		Oats	
Location	pCi Sr-90/kg	S.U.	pCi Sr-90/kg	S.U.	pCi Sr-90/kg	S.U.	pCi Sr-90/kg	S.U.
Tylstrup	89 ± 12	233 ± 44	60 ± 1	120 ± 24	w: 61 ± 9 s: 71 ± 7	w: 114 ± 17 s: 151 ± 9	83 ± 1	97 ± 2
Studsgård	w: 191 ± 1 s: 129 ± 4	w: 462 ± 33 s: 280 ± 24	158 ± 11	332 ± 43	w: 150 ± 7 s: 120 ± 6	w: 404 ± 19 s: 282 ± 18	92 ± 2	128 ± 6
Ødum	99 ± 9	228 ± 16	61 ± 7	133 ± 15	w: 70 ± 10 s: 75 ± 11	w: 140 ± 24 s: 178 ± 18	53 ± 4	68 ± 5
Askov	143 ± 34	229 ± 64	163 ± 39	246 ± 66	104 ± 4	254 ± 1	70 ± 1	85 ± 2
St. Jyndevad	161 ± 15	384 ± 28	102 ± 4	258 ± 8	109 ± 20	394 ± 29	125 ± 8	160 ± 9
Blangstedgård	87 ± 21	222 ± 4	71 ± 4	126 ± 2	75 ± 10	174 ± 17	56 ± 8	68 ± 7
Tystofte	114 ± 41	160 ± 14	58 ± 5	103 ± 12	w: 73 ± 5 s: 87 ± 5	w: 173 ± 6 s: 168 ± 9	74 ± 3	93 ± 8
Virumgård	62 ± 1	177 ± 2	66 ± 5	129 ± 15	w: 89 ± 4 s: 98 ± 4	w: 239 ± 18 s: 187 ± 21	134 ± 9	174 ± 17
Abed	59 ± 13	116 ± 26	41 ± 4	80 ± 4	w: 73 ± 3 s: 63 ± 4	w: 176 ± 14 s: 110 ± 14	56 ± 4	66 ± 1
Åkirkeby	84 ± 14	185 ± 27	64 ± 2	140 ± 10	w: 88 ± 1 s: 67 ± 4	w: 215 ± 18 s: 131 ± 6	67 ± 2	79 ± 7
Mean	111	241	86	167	87	205	81	102

The error terms are the S.E. of the mean of double determinations. The relative S.D. due to chemical processing and counting is approx. 18%. The error from sampling equals that from chemical processing and counting. s stands for spring variety and w for winter variety. The means in the table are based on both spring and winter varieties.

Table 5.3.2

Analysis of Variance of ln S.U. in Grain in 1965
(from table 5.3.1)[x]

Variation	n/40 SSD	f	s^2	v^2	P
Between locations	4.3513	9	0.4834	8.77	> 99.95%
Between sorts	4.4357	3	1.4786	26.83	> 99.95%
Remainder	1.4864	27	0.0551		
Total	10.2734	39			
η = 0.24					

[x] Only winter-variety figures were used for rye and wheat.

Table 5.3.3

Analysis of Variance of ln pCi Sr-90/kg Grain in 1965
(from table 5.3.1)[x]

Variation	n/40 SSD	f	s^2	v^2	P
Between locations	3.5864	9	0.3984	6.12	> 99.95%
Between sorts	0.5149	3	0.1716	2.64	
Remainder	1.758o	27	0.0651		
Total	5.8593	39			
η = 0.26					

[x] Cf. the note to table 5.3.2

Table 5.3.4

Calsium-137 in Grain in 1965

	Rye		Barley		Wheat		Oats	
Locations	pCi Cs-137/kg	M.U.	pCi Cs-137/kg	M.U.	pCi Cs-137/kg	M.U.	pCi Cs-137/kg	M.U.
Tylstrup	165	44	158	26	w: 219 s: 102	w: 67 s: 30	125	37
Studsgård	w: 570 s: 380	w: 110 s: 106	212	66	w: 222 s: 165	w: 66 s: 52	161	54
Ødum	246	65	125	37	w: 165 s: 88	w: 52 s: 27	166	54
Askov	460	98	208	51	223	58	149	42
St. Jyndevad	475	110	220	44	257	74	248	83
Blangstedgård	176	49	143	34	113	31	118	36
Tystofte	250	67	182	34	w: 163 s: 151	w: 38 s: 43	124	40
Virumgård	247	55	118	22	w: 134 s: 102	w: 41 s: 30	120	35
Abed	164	46	182	36	w: 144 s: 138	w: 47 s: 43	110	40
Åkirkeby	292	100	247	60	w: 170 s: 159	w: 45 s: 48	148	55
Mean	311	77	180	41	160	46	147	48

The coefficient of variation of the results is 21%. All determinations were carried out on fresh grain by γ-spectrometry. s stands for spring variety and w for winter variety.

Table 5.3.5

Analysis of Variance of ln M.U. in Grain in 1965 (from table 5.3.4)[x]

Variation	n/40 SSD	f	s^2	v^2	P
Between locations	2.5140	9	0.2793	6.73	> 99.95%
Between sorts	1.8179	3	0.6060	14.60	> 99.95%
Remainder	1.1197	27	0.0415		
Total	5.4516	39			
η = 0.21					

[x] Cf. note to table 5.3.2

Table 5.3.6

Analysis of Variance of ln pCi Cs-137/kg Grain in 1965 (from table 5.3.4)[x]

Variation	n/40 SSD	f	s^2	v^2	P
Between locations	2.3935	9	0.2659	6.17	> 99.95%
Between sorts	2.3700	3	0.7900	18.33	> 99.95%
Remainder	1.1642	27	0.0431		
Total	5.9277	39			
η = 0.21					

[x] Cf. note to table 5.3.2

cereals). As is known from the stable-strontium measurement on grain (cf. table 5.3.7), rye has a smaller root uptake of strontium than e.g. wheat; hence it is to be expected that, when the direct contamination with Sr-90 decreases in comparison with the root uptake, the difference between the Sr-90 levels found in grain of rye and wheat will decrease. This is in agreement with the actual observations in 1965, when the ratio $\frac{\text{pCi Sr-90/kg rye}}{\text{pCi Sr-90/kg wheat}}$ was 1.3 as compared with 1.8 in 1964.

Table 5.3.4 shows the measurements of Cs-137 in grain in 1965, table 5.3.5 the analysis of variance of the M.U. figures and table 5.3.6 the analysis of variance of the pCi Cs-137/kg grain figures. The variation between locations as well as that between species were highly significant. The Cs-137 content in grain from eastern Denmark was on the average approx. 75% (M.U. figures) of the grain level in Jutland, and the Cs-137 level in rye (pCi/kg figures) was on the average approx. twice that in the other cereals.

If the S. U. levels in grain from the harvest of 1965 are compared with the levels from 1964[9], we find the 1965 figures to be smaller by a factor of approx. 2.1. If, however, the Sr-90 fall-out rates in the periods July-August 1964 and 1965 are compared, we find the 1964 figures to be on the average larger by a factor of three than the 1965 figures (cf. 4.1 and ref. 9)). This shows that the fall-out rate was not the only factor determining the Sr-90 level in grain.

The Cs-137 content in grain from the 1965 harvest was on the average approx. one third the 1964 level. The fall-out rate in May-August 1964 was three times that in May-August 1965 (cf. 4.1 and ref. 9. The period May-August was selected because experiments have shown[18] that the contamination of grain with Cs-137 originates from the period before the emergence of the ears). This fits the hypothesis that the Cs-137 level in grain depends mainly upon the fall-out rate.

Table 5.3.7

mg Sr/g Ca in Grain from 1965

	Rye	Barley	Wheat	Oats
Tylstrup	2.1 ± 0.5	3.1 ± 0.4	(s: 3.8 ± 0.4) 4.1 ± 1.4^x	1.3 ± 0.1
Studsgård	(s: 3.4 ± 0.8^x) 3.1 ± 0.1	4.3 ± 0.9	(s: 7.8 ± 1.2^x) 7.1 ± 2.7^x	2.9 ± 0.9^x
Ødum	0.6 ± 0.1	1.3 ± 0.3	(s: 2.8 ± 0.8) 3.0 ± 0.2	1.7 ± 0.8
Askov	2.9 ± 0.8	2.7 ± 0.6	3.4 ± 0.2	1.9 ± 0.8
St. Jyndevad	2.6 ± 0.3	2.4 ± 0.4	3.7 ± 0.3	2.1 ± 0.4
Blangstedgård	3.5 ± 1.6^x	4.0 ± 0.8	7.6 ± 1.2^x	1.4 ± 0.6^x
Tystofte	2.1 ± 0.6	1.8 ± 0.4	(s: 1.5 ± 0.5^x) 2.7 ± 0.7^x	3.7 ± 1.4^x
Virumgård	5.3 ± 0.6	3.8 ± 0.9^x	(s: 3.6 ± 0.4) 7.1 ± 2.0^x	3.1 ± 0.9
Abed	1.1 ± 0.5	2.4 ± 0.1	(s: 2.7 ± 0.7) 2.9 ± 1.1^x	1.6 ± 0.5
Åkirkeby	2.0 ± 0.1	4.4 ± 0.4	(s: 2.0 ± 0.6) 3.4 ± 1.2^x	2.8 ± 0.6

The analyses were double determinations except those marked with ^{x}, which indicates a triple determination. The error term is the S. E. of the mean. s: spring variety. The figures in brackets were omitted in the analysis of variance in table 5.3.8.

Table 5.3.8

Analysis of Variance of ln mg Sr/g Ca in Grain from 1965 (from table 5.3.7)

Variation	n/40 SSD	f	s^2	v^2	P
Between locations	3.8691	9	0.4299	3.20	> 99%
Between sorts	2.5415	3	0.8471	6.31	> 99.5%
Remainder	3.6279	27	0.1343		
Total	10.0385	39			
η = 0.38					

The mean ratio between pCi Cs-137/kg grain and pCi Sr-90/kg grain was 2.2, i.e. markedly below the ratio 3.1 found in 1964. Also this is in agreement with the decreasing contribution from the fall-out rate (determining both Cs-137 and Sr-90) as compared with accumulated fall-out (of importance only for Sr-90).

An analysis of variance of ln (pCi Cs-137/pCi Sr-90) showed no significant difference either between locations or between sorts, probably because the coefficient of variation of the results was too big (η = 0.35).

Table 5.3.7 shows the stable-strontium content in grain in relation to the calcium content, and table 5.3.8 is an analysis of variance of the figures. There were significant differences between both locations and sorts. As in the previous years[7, 8, 9], wheat contained more and rye less stable strontium per g Ca than the average, and Virumgård and Studsgård showed higher levels than e.g. Ødum and Abed. The relatively high levels at Blangstedgård as compared with previous years were probably due to the fact that the grain samples in 1965 were obtained from a neighbouring farm, possibly with other soil characteristics (mg stable Sr/g Ca ratio, e.g.) than Blangstedgård.

5.4. Sr-90 and Cs-137 in Bread from the Entire Country

In 1965 samples of white bread (75% extraction) and dark rye bread (100% extraction) were collected as previously all over the country in June and December (in both A and B towns, cf. figs. 5.2.1 and 5.2.2). The samples were combined into eight zone samples and a sample from Copenhagen, and Sr-90 and Cs-137 were determined. The Cs-137 determinations were carried out on dried samples by γ-spectroscopy.

Tables 5.4.1 and 5.4.2 show the results. In figs. 5.4.1 and 5.4.2 a comparison with grain levels is made for the years 1962-1965. It is

Table 5.4.1

Sr-90 in Danish Bread in 1965

	June				December			
	White bread		Rye bread		White bread		Rye bread	
	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.
I	22.3 ± 1.4	11.2 ± 0.7	189.2 ± 7.3	54.7 ± 2.7	27.9 ± 3.3	13.9 ± 1.8	109.8 ± 4.3	35.1 ± 1.7
II	23.8 ± 1.4	11.6 ± 0.4	178.5 ± 3.5	45.9 ± 0.8	22.8 ± 0.8	12.0 ± 0.5	112.8 ± 4.8	36.1 ± 1.5
III	25.7 ± 1.8	13.3 ± 0.3	149.5 ± 24.5	47.5 ± 7.0	20.7 ± 0.7	17.6 ± 1.9	106.1 ± 8.2	42.2 ± 5.6
IV	26.2 ± 0.4	11.9 ± 0.3	153.9 ± 13.9	53.9 ± 5.7	24.4 ± 1.2	12.4 ± 0.6	83.7 ± 2.4	28.1 ± 0.8
V	24.6 ± 0.6	11.3 ± 0.3	121.1 ± 4.1	38.8 ± 0.2	16.0 ± 0.5	9.2 ± 0.2	80.6 ± 5.3	22.9 ± 1.0
VI	26.2 ± 0.7	10.8 ± 0.4	128.4 ± 1.4	38.4 ± 0.2	25.0 ± 2.8	11.2 ± 0.8	86.5 ± 18.0	25.8 ± 5.4
VII	25.8 ± 1.3	10.2 ± 0.8	107.5 ± 0.5	31.4 ± 3.1	17.3 ± 1.9	8.0 ± 0.3	71.9 ± 1.3	24.3 ± 0.4
VIII	33.0 ± 4.8	16.1 ± 2.9	103.0 ± 1.0	38.0 ± 1.1	25.0 ± 0.1	17.7 ± 3.0	82.9 ± 12.2	24.0 ± 7.2
Mean	26.0	12.1	142.4	43.7	22.5	12.6	92.0	29.9
Copenhagen	28.5 ± 2.1	12.8 ± 0.5	128.5 ± 0.5	46.4 ± 1.1	17.5 ± 0.2	9.9 ± 0.4	78.2 ± 0.1	27.6 ± 1.5
Population-weighted mean	25.9	12.0	145.5	45.4	20.1	11.8	92.4	30.8

The error term is the S.E. of the mean of double determinations. The relative errors due to radiochemical analysis and counting were 11% for the pCi Sr-90/kg figures and 14% for the S.U. figures.

Table 5.4.2

Cs-137 in Danish Bread in 1965

	June				December			
	White bread		Rye bread		White bread		Rye bread	
	pCi/kg	M.U.	pCi/kg	M.U.	pCi/kg	M.U.	pCi/kg	M.U.
I	254	143	811	244	358	246	428	133
II	123	98	795	210	285	221	530	167
III	150	105	746	201	211	187	420	140
IV	235	160	705	142	246	184	350	117
V	227	153	598	159	226	212	420	131
VI	260	145	539	157	292	194	350	117
VII	233	178	460	136	216	160	340	118
VIII	194	154	454	132	198	173	288	100
Mean	210	142	639	173	254	197	391	128
Copenhagen	123	91	830	204	387	270	398	133
Population-weighted mean	179	119	729	193	304	225	415	135

The samples were identical with those in which Sr-90 was determined (cf. table 5.4.1). The γ-counting was carried out on frech samples. The relative error of the result is estimated to be 15%.

assumed that the bread consumed in the first nine months of the i^{th} year has been made of grain from the harvest in the $(i-1)^{th}$ year, while the bread consumed in the last three months has come from the harvest in the i^{th} year. Further it is assumed that 1 kg flour yields 1.35 kg bread[19] and that wheat flour of 75% extraction contains 20% of the Sr-90 and 50% of the Cs-137 found in wheat grain[5, 8, 9].

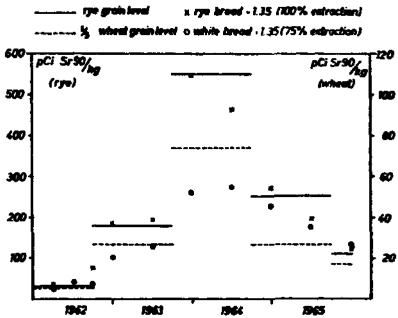

Fig. 5.4.1. Comparison of Sr-90 in bread and grain, 1962-65.

Fig. 5.4.1 shows that the Sr-90 levels in rye bread were in reasonable agreement with those in rye grain according to the above-mentioned model. However, the rye-bread levels in June 1964 and 1965 were somewhat below the expected values, probably because approx. 15% foreign flour was added to the Danish flour from the harvests 1963 and 1964. As regards white bread and wheat, it is evident from the figure that the wheat flour used for white bread is normally older than the rye flour used for rye bread; therefore the curve for the activity in white bread is smoother than that for wheat grain.

As regards Cs-137, fig. 5.4.2 shows that the fit to the model is rather bad. For the measurements in December 1963 and June 1964 (indicated in brackets) this might be so because these bread samples were measured as ashed samples, which probably reduced the Cs-137 level in comparison with that in grain.

Further it is evident that the Cs-137 bread levels in December 1965 were definitely higher than if the bread had been made of grain from the 1965 harvest; this was especially the case with white bread (cf. 5.9.13).

On comparison of the bread levels in Jutland with those in East Denmark it appeared that the rye bread level in Jutland was approx. 1.4

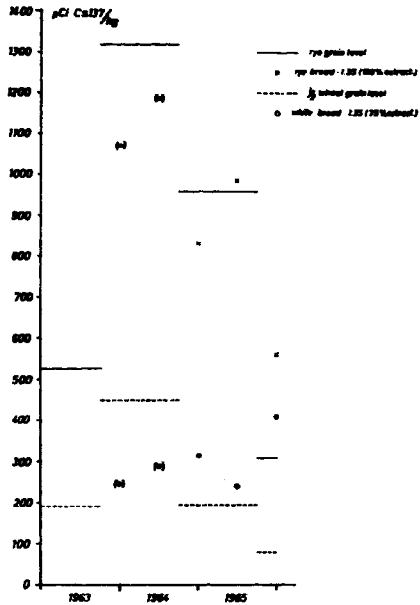

Fig. 5.4.2. Comparison of Cs-137 in bread and grain, 1962-65.

times that in East Denmark, whereas the white bread levels did not differ significantly in the two parts of the country.

It is concluded that while it is rather easy to predict the Sr-90 (and Cs-137) level in rye bread from that in rye grain, it is not so easy to do the same for white bread through wheat grain. The main reason is that the wheat flour seems to be more mixed up than the rye flour, partly with older flour, partly with flour of grain from other parts of the country than where the bread is consumed.

5.5. Sr-90 and Cs-137 in Potatoes from the Entire Country

The samples of potatoes were collected in September from the ten state experimental farms (cf. fig. 4.1.1) and analysed for Sr-90 and Cs-137 (γ-spectroscopy of dried potatoes).

Table 5.5.1

Sr-90 and Cs-137 in Danish Potatoes in 1965

Location	pCi Sr-90/kg	S.U.	pCi Cs-137/kg	M.U.
Tylstrup	3.1 ± 0.2	110	21.6	4.7
Studsgård	7.0 ± 0.2	126	32.9	7.3
Ødum	2.9 ± 0.2	41 ± 1	19.3	4.1
Askov	4.4 ± 0.3	70	16.0	3.8
Jyndevad	2.3 ± 0.6	58	48.8	12.5
Blangstedgård	4.3 ± 0.4	54	12.0	2.8
Tystofte	2.6 ± 0.1	37 ± 7	15.3	3.0
Virumgård	4.8 ± 0.2	65 ± 2	13.2	2.7
Abed	2.4 ± 0.1	24 ± 2	18.9	4.4
Åkirkeby	3.6 ± 0.8	56	24.2	6.2
Mean	3.7	64	22.2	5.2

The error term is the S.E. of the mean of double drterminations. The relative S.D. of the pCi Sr-90/kg figures due to radiochemical analysis and counting is 13.5%. Cs-137 was determined by γ-counting on the dried potatoes, and the relative counting error was approx. 15%.

Table 5.5.2

Analysis of Variance of ln pCi Sr-90/kg in Potatoes in 1962-65
(from table 5.5.1 and refs. 7, 8 and 9)

Variation	n/84 SSD	f	s^2	v^2	P
Between years	2.1383	3	0.7128	6.25	> 99.5%
Between locations	1.3181	9	0.1465	1.28	~ 70%
Remainder	3.0790	27	0.1140		
Total	6.5354	39			
η = 0.35					

Table 5.5.3

Analysis of Variance of ln pCi Cs-137/kg in Potatoes, 1963-65
(from table 5.5.1 and refs. 8 and 9)

Variation	n/30 SSD	f	s^2	v^2	P
Between years	12.3102	2	6.1551	55.95	> 99.95%
Between locations	1.7857	9	0.1984	1.80	> 70%
Remainder	1.9807	18	0.1100		
Total	16.0767	29			
η = 0.34					

Table 5.5.1 shows the Sr-90 and Cs-137 contents in potatoes. The mean contents for the country were 3.7 pCi Sr-90/kg or 64 S.U. and 22 pCi Cs-137/kg or 5 M.U. The pCi Sr-90/kg figures were approx. 11% higher for Jutland than for eastern Denmark, i.e. hardly significant. The Cs-137 content in potatoes from Jutland was approx. 66% greater than that in potatoes from eastern Denmark.

The Sr-90 content in potatoes decreased by a factor of nearly 1.3 from 1964 to 1965 and Cs-137 by a factor of approx. two. The mean of the Cs-137/Sr-90 ratios (pCi/kg figures) was 6 (in 1964: 9).

Tables 5.5.2 and 5.5.3 show the analyses of variance of the Sr-90 and Cs-137 contents in potatoes in the last few years. The variation between years was highly significant whereas it was impossible to show a significant variation between locations.

5.6. Sr-90 and Cs-137 in Vegetables and Fruits from the Entire Country

In 1965 the country-wide collection of vegetables and fruits from the 48 towns in the eight zones (cf. figs. 5.2.1 and 5.2.2) and from Copenhagen was continued in accordance with the principles laid down in 1964[9]. The sampling took place in September and December. Tables 5.6.1 - 5.6.4 show the results and tables 5.6.5 - 5.6.8 the analyses of variance, which were calculated by means of the VAR-3 programme[20] on the Risö GIER computer.

Table 5.6.1

pCi Sr-90/kg in Vegetables and Fruit in 1965

Zone	Peas	Carrots	Onions	Apples	Prunes	Straw-berries	Cabbage	Kale	Red cabbage
I	6.5	16.0 ± 1.8	13.8	2.9	2.2	18.3	21.1	108.9	8.3
II	13.7	28.5 ± 0.2	16.5	2.9	1.5	19.2	19.8	117.3	12.6
III	13.4	31.2	18.8	2.8	4.2	21.0 ± 1.6	19.9	88.4	17.6
IV	8.2	49.0	15.6	2.8	3.0	13.0	19.9	134.8	13.5
V	(9.0)	21.9	16.0	3.1	2.9	22.1	18.7	112.1	11.5
VI	(6.6)	9.7	13.6	2.7	4.6	32.3 ± 2.5	7.6	60.7	5.6
VII	3.9	8.8 ± 3.2	11.4	1.6	3.8	12.4 ± 4.6	9.4	233.7	5.3
VIII	(6.1)	18.2	21.3	2.4	3.6			36.2	7.3
Mean	8.4	22.9	15.9	2.7	3.2	19.8	16.6	111.5	10.2
Copenhagen		9.9	8.9	2.6	2.3	19.2 ± 2.9	12.7	72.8	8.8
Population-weighted mean	(8.4)	19.1	13.7	2.8	2.9	20.9	15.7	94.9	10.3

The error terms are the S.E. of the mean of double determinations. The estimated error of the Sr-90 analysis was approx. 20%. The figures in brackets were calculated from VAR 3 (cf. 1.2).

Table 5.6.2

S. U. in Vegetables and Fruit in 1965

Zone	Peas	Carrots	Onions	Apples	Prunes	Straw-berries	Cabbage	Kale	Red cabbage
I	23.3	50.9±6.5	60.6	63.1	37.0	95.0	38.5	27.8	21.4
II	51.5	79.8±1.3	79.3	61.6	15.3	98.5	39.7	34.2	31.2
III	44.8	85.4	88.0	56.7	45.8	99.7±0.8	44.6	20.2	40.7
IV	23.3	167.2	47.9	70.3	40.4	84.3±4.1	30.5	32.1	37.1
V	(26.8)	65.3	60.2	58.2	30.8	111.3	30.0	20.3	23.3
VI	(19.9)	26.4	61.7	58.2	48.5	80.2	17.2	11.6	14.2
VII	11.6	27.8±12.1	33.2	30.9	29.6	54.4±7.7	18.6	34.4	10.8
VIII	(20.3)	63.4	80.4	43.3	44.1			12.1	11.5
Mean	27.7	70.8	63.9	55.3	36.4	89.1	31.3	24.1	23.8
Copenhagen		37.0	34.8	73.1	28.5	76.8±3.5	21.9	30.6	26.2
Population-weighted mean	(27.7)	58.6	58.4	62.4	32.7	87.1	29.7	26.0	25.5

Cf. note to table 5.6.1.

Table 5.6.3

pCi Cs-137/kg in Vegetables and Fruit in 1965

Zone	Peas	Carrots	Onions	Apples	Prunes	Straw-berries	Cabbage	Kale	Red cabbage
I	29.3	(15.2)	(10.4)	45.5	39.8	23.5	12.4	153.6	10.3
II	16.1	18.0	(10.1)	60.8	61.0	(32.5)	8.2	88.9	11.4
III	20.9	27.5	16.4	53.4	16.8	30.5	23.2	73.1	11.8
IV	10.7	11.8	(9.1)	43.2	58.4	(29.4)	13.0	64.0	15.9
V	(15.8)	6.4	(10.0)	52.4	69.4	29.8	10.7	85.0	20.3
VI	(12.4)	11.9	8.8	38.1	45.5	45.3	6.3	61.1	(11.8)
VII	7.7	16.8	5.2	(41.3)	82.6	26.1	5.8	123.6	(11.3)
VIII	(13.1)	17.0	9.4	36.1	38.2		9.9	58.5	(11.4)
Mean	16.6	15.6	9.7	46.6	51.5	30.4	11.2	86.5	13.0
Copenhagen		19.5	6.8	43.2	32.7	38.3	5.1	50.6	5.2
Population-weighted mean	(15.6)	17.0	9.3	47.5	44.0	34.1	9.7	78.2	10.6

The estimated error of the γ-measurements was approx. 25%.
The figures in brackets were calculated from VAR 3 (cf. 1.2).

Table 5.6:4

M. U. in Vegetables and Fruit in 1965

Zone	Peas	Carrots	Onions	Apples	Prunes	Straw-berries	Cabbage	Kale	Red cabbage
I	9.8	(6.0)	(5.1)	42.0	30.0	16.2	5.2	19.1	3.7
II	4.3	5.9	(4.3)	54.0	34.8	(19.1)	3.6	12.0	4.0
III	7.9	12.8	6.8	40.0	11.8	18.5	8.6	8.7	4.0
IV	3.3	5.6	(4.3)	41.0	38.0	(18.3)	5.7	8.0	5.3
V	(4.6)	2.9	(4.3)	47.5	44.5	18.2	4.4	11.3	6.1
VI	(3.9)	6.7	4.2	40.5	22.0	20.3	2.6	8.0	(3.6)
VII	2.4	9.5	3.0	(40.5)	51.0	} 21.3	2.6	13.7	(4.1)
VIII	(4.5)	7.5	3.4	37.4	24.4		4.9	11.1	(4.1)
Mean	5.1	7.4	4.4	42.9	32.1	19.3	4.7	11.5	4.4
Copenhagen		9.0	3.0	36.2	20.6	23.8	1.9	6.7	2.0
Population-weighted mean	(5.1)	7.8	4.3	42.2	27.0	20.3	3.9	10.1	3.6

Cf. note to table 5.6.3

The variations between sorts were significant as regards both Sr-90 and Cs-137 activity. The highest Sr-90 and Cs-137 levels (pCi/kg) were found in kale, the lowest Sr-90 levels in apples and prunes and the lowest Cs-137 levels in onions and red cabbage.

It was not possible to demonstrate any significant variation between locations for Cs-137 activity in vegetables and fruits, whereas it was evident that the Sr-90 levels in East Denmark, especially in zone VII, were significantly lower than those found in Jutland (zones I-IV). Vegetables and fruit from Jutland thus showed S. U. levels 50% higher on the average than those encountered in East Denmark.

Table 5.6.9 shows a calculation of the mean contents of Sr-90 and Cs-137 in Danish vegetables collected in 1965. The percentage contributions were taken from the production data for the period 1952-55[19], and the

Table 5.6.5

Analysis of Variance of ln pCi Sr-90/kg Vegetables and Fruits in 1965 (from table 5.6.1)

Variation	n/72 SSD	f	s^2	v^2	P
Between locations	3.5751	7	0.5107	3.08	> 99%
Between sorts	75.5657	8	9.4457	56.94	> 99.95%
Remainder	8.7913	53	0.1659		
Total	87.9321	68			
η = 0.42					

Table 5.6.6

Analysis of Variance of ln S.U. in Vegetables and Fruits in 1965
(from table 5.6.2)

Variation	n/72 SSD	f	s^2	v^2	P
Between locations	5.1318	7	0.7331	5.20	> 99.95%
Between sorts	14.6881	8	1.8360	13.02	> 99.95%
Remainder	7.4745	53	0.1410		
Total	27.2944	68			
η = 0.39					

Table 5.6.7

Analysis of Variance of ln pCi Cs-137/kg Vegetables and Fruits in 1965
(from table 5.6.3)

Variation	n/72 SSD	f	s^2	v^2	P
Between locations	0.5174	7	0.0739		
Between sorts	34.6461	8	4.3307	9.93	> 99.95%
Remainder	17.8818	41	0.4361		
Total	53.0453	56			
η = 0.73					

Table 5.6.8

Analysis of Variance of ln M.U. in Vegetables and Fruits in 1965
(from table 5.6.4)

Variation	n/72 SSD	f	s^2	v^2	P
Between locations	0.4842	7	0.0692		
Between sorts	43.1570	8	5.3946	36.18	> 99.95%
Remainder	6.2620	42	0.1491		
Total	49.9032	57			
η = 0.40					

levels were the population-weighted means calculated in tables 5.6.1 - 5.6.4. The mean contents in vegetables from 1965 were found to be 13.8 pCi Sr-90/kg (34.9 S.U.) and 14.0 pCi Cs-137/kg (5.0 M.U.).

Table 5.6.10 shows a similar calculation of the levels found in Danish fruit in 1965.

"Apple and pear" were based solely on apples. "Other tree fruits" were represented by prunes, "berries" by strawberries and cucumber by

Table 5.6.9

Calculated Sr-90 and Cs-137 Mean Levels in Vegetables Collected from the Whole Country in 1965

Daily intake in g	Sort	%	pCi Sr-90/kg	S.U.	pCi Cs-137/kg	M.U.
	Cabbage (red, white and spring)	83	13.0	27.6	10.2	3.8
	Cauliflower	10	(13.0)	(27.6)	(10.2)	(3.8)
	Brussels sprout	3	(13.0)	(27.6)	(10.2)	(3.8)
	Kale	4	94.9	26.0	78.2	10.1
50	Leafy Vegetables	100	16.3	26.4	12.9	4.1
	Carrot	34	19.1	58.6	17.0	7.8
	Celery root	15	(16.4)	(58.5)	(13.2)	(6.0)
	Beetroot	14	(16.4)	(58.5)	(13.2)	(6.0)
	Leek	16	(16.4)	(58.5)	(13.2)	(6.0)
	Onion	21	13.7	58.4	9.3	4.3
30	Root vegetables	100	16.8	58.5	13.7	6.3
	Pea	95	8.4	27.7	15.6	5.1
	Bean	5	(8.4)	(27.7)	(15.6)	(5.1)
40	Pea and bean	100	8.4	27.7	15.6	5.1
120	Vegetables total	-	13.8	34.9	14.0	5.0

The Sr-90 and Cs-137 levels in cauliflower and Brussels sprout were assumed to be equal to the levels in cabbage. The levels in celery root, beet root and leek were estimated as the mean of the levels in carrot and onion. The levels in bean were assumed to be equal to those in pea.

Table 5.6.10

Calculated Sr-90 and Cs-137 Mean Levels in Fruits Collected from the Whole Country in 1965

Sort	%	pCi Sr-90/kg	S.U.	pCi Cs-137/kg	M.U.
Apple and pear	80	2.8	62.4	47.5	42.2
Other tree fruits	5	2.9	32.7	44.0	27.0
Berries	10	20.9	87.1	34.1	20.3
Cucumber	5	(13.0)	(27.6)	(10.2)	(3.8)
Fruit	100	5.1	61.6	44.1	37.3

The Sr-90 and Cs-137 levels in Cucumber were assumed to be equal to the levels in cabbage (cf. table 5.6.9) cabbage. The mean levels in Danish fruit collected in 1965 were 5.1 pCi Sr-90/kg (62 S.U.) and 44 pCi Cs-137/kg (37 M.U.).

The 1965 Sr-90 levels in vegetables and fruits were 84% and 28% respectively of the 1964 levels, and for Cs-137 the corresponding percentages were approx. 40% and 60%. This shows that whereas Sr-90 in vegetables depends to a great extent on the accumulated fall-out, Sr-90 in fruits and Cs-137 in vegetables and fruits depend mainly on the fall-out rate.

5.7. Sr-90 and Cs-137 in Total Diet from the Entire Country

In 1965 total-food samples representing an average Danish diet according to Hoff-Jørgensen (cf. Appendix B in Risö Report No. 63[7]) were collected according to the principles followed in 1961-64. As in 1964, two groups of towns (A and B, cf. 5.2.1 and 5.2.2) supplied the samples.

Tables 5.7.1 and 5.7.2 show the results. The population-weighted mean levels were 21.4 S.U. and 261 pCi Cs-137/day in June and 18.3 S.U. and 193 pCi Cs-137/day in December. As in the previous years[6-9], the variation between locations was significant. The S.U. levels in the total diet were approx. 40% higher in Jutland than in eastern Denmark. They decreased by a factor of approx. 1.17 from June to December.

Table 5.7.1

Sr-90 and Cs-137 in Danish Total Diet Collected in June 1965

Zone	S.U.	pCi Sr-90/day	g Ca/day	mg Sr/g Ca	M.U.	pCi Cs-137/day
I: North Jutland	25.1 ± 2.1	48.0 ± 2.9	1.85 ± 0.03	2.0 ± 0.1	80 ± 4	300 ± 18
II: East Jutland	26.4 ± 3.3	47.3 ± 7.9	1.78 ± 0.06	1.6 ± 0.4	77 ± 9	263 ± 35
III: West Jutland	26.2 ± 1.3	45.2 ± 2.9	1.73 ± 0.02	1.3 ± 0.3	76 ± 4	272 ± 1
IV: South Jutland	22.8 ± 0.9	40.0 ± 2.7	1.75 ± 0.04	1.4 ± 0.3	87 ± 6	304 ± 7
V: Funen	19.1 ± 1.6	34.0 ± 2.2	1.79 ± 0.03	1.5 ± 0.4	70 ± 1	260 ± 21
VI: Sealand	16.1 ± 1.3	30.8 ± 2.5	1.90 ± 0.01	2.0 ± 0.1	63 ± 6	232 ± 18
VII: Lolland-Falster	18.0 ± 2.2	31.0 ± 1.5	1.72 ± 0.07	2.3 ± 0.7	53 ± 9	208 ± 23
VIII: Bornholm	18.6 ± 2.2	32.2 ± 2.5	1.74 ± 0.07	1.9 ± 0.1	49 ± 10	177 ± 22
Mean	21.5	38.3	1.78	1.8	69	252
Copenhagen	18.6 ± 0.4	34.6 ± 1.3	1.86 ± 0.02	1.6 ± 0.1	65	257
Population-weighted mean	21.4	38.7	1.82	1.7	71	261
Relative S.D. due to sampling and analysis	13%	13%	4%	28%	14%	11%

The error terms are the S.E. of the mean. The samples were collected in A and B towns in the eight zones, and the analyses were carried out as single determinations for each of the two town groups, i.e. the errors comprise both sampling, analytical and counting errors.

Table 5.7.2

Sr-90 and Cs-137 in Danish Total Diet Collected in December 1965

Zone	S.U.	pCi Sr-90/day	g Ca/day	mg Sr/g Ca	M.U.	pCi Cs-137/day
I: North Jutland	21.9 ± 1.5	37.3 ± 2.8	1.71 ± 0.01	1.6 ± 0.1	53 ± 1	222 ± 1
II: East Jutland	21.5 ± 0.5	37.5 ± 0.7	1.74 ± 0.06	1.7 ± 0.4	41 ± 1	195 ± 22
III: West Jutland	22.4 ± 0.4	34.4 ± 0.3	1.54 ± 0.01	1.7 ± 0.4	50 ± 11	239 ± 30
IV: South Jutland	20.0 ± 1.4	34.2 ± 1.1	1.71 ± 0.06	1.9 ± 0.2	56 ± 6	225 ± 37
V: Funen	15.4 ± 1.4	29.0 ± 1.0	1.88 ± 0.01	1.3 ± 0.1	41 ± 4	163 ± 15
VI: Sealand	15.7 ± 1.1	29.4 ± 2.0	1.87 ± 0.01	2.0 ± 0.6	44 ± 15	184 ± 24
VII: Lolland-Falster	13.2 ± 0.3	23.6 ± 0.8	1.79 ± 0.10	2.3 ± 0.3	35 ± 3	155 ± 6
VIII: Bornholm	15.6 ± 0.9	31.7 ± 0.3	2.05 ± 0.09	1.1 ± 0.2	31 ± 7	116 ± 20
Mean	18.2	32.1	1.79	1.7	44	187
Copenhagen	15.8 ± 0.9	32.6 ± 5.4	1.80 ± 0.02	1.8 ± 0.3	39	175
Population-weighted mean	18.3	33.1	1.76	1.7	44	193
Relative S.D. due to sampling and analysis	7%	6%	4%	26%	25%	17%

The error terms are the S.E. of the mean. Cf. note to table 5.7.1.

Fig. 5.7.1 shows the zone mean levels (not population weighted) of S.U. in total diet since May 1961.

The 1965 Sr-90 levels in total diet were approx. 59% of the 1964 levels, while the Cs-137 levels were approx. 77% of the 1964 ones. This is a little surprising as it was to be expected that Cs-137 would decrease more rapidly than Sr-90 because of its closer relationship with the fall-out rate. As shown in 5.4, bread contained relatively much Cs-137 in 1965 as compared with Sr-90. Bread might thus be the diet component responsible for the rather high Cs-137 level in total diet in 1965 (cf. 5.9.13).

The ratio S.U. in total diet/S.U. in milk was calculated for the period June 1962 - December 1965; the mean was 1.47. An analysis of variance showed significant variations between both months and locations. Fig. 5.7.2 shows the variation of the ratio with time. As regards locations, it is interesting to notice that the mean ratio for Jutland was 1.32 while it was 1.62 in East Denmark, i.e. 23% higher. The reason for this difference is the relatively high Sr-90 levels in milk from Jutland (cf. 5.2).

As regards the ratio between Sr-90 in the total diet and Sr-90 coming from the rye bread and white bread in the diet (cf. fig. 5.7.3), an analysis of variance proved significant variation only between months, not between locations. The mean ratio for the period considered was 2.13, and unlike the diet/milk ratio it shows a minimum in 1963-64. This fits the hypothesis

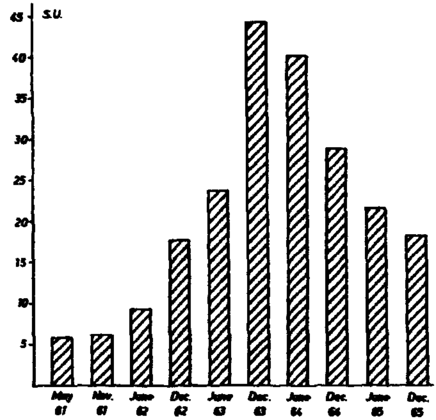

Fig. 5.7.1. S.U. in samples of total Danish diet collected in 1961-65.

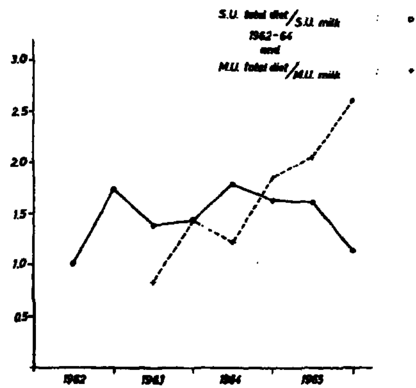

Fig. 5.7.2. The S.U. total diet/S.U. milk (o) ratio and the M.U. total diet/M.U. milk ratio (+) in Denmark, 1962-65.

Fig. 5.7.3. The pCi Sr-90 in total diet/pCi Sr-90 in rye bread + white bread ratio in Denmark, 1962-65.

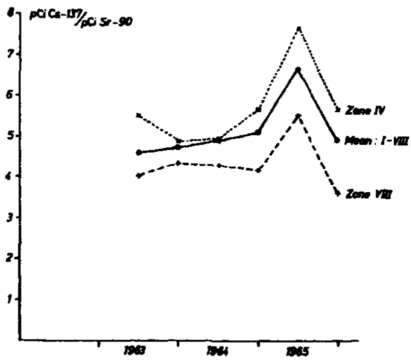

Fig. 5.7.4. The Cs-137/Sr-90 ratio in the total diet, 1963-65.

that Sr-90 in bread originates from direct contamination to a higher degree than Sr-90 in other diet components, while the Sr-90 level in milk depends more on the root uptake than that in grain products.

Fig. 5.7.4 shows the Cs-137/Sr-90 ratio in the total Danish diet since 1963. An analysis of variance shows significant variation between months as well as between locations. The maximum in June 1965 coincides with rather high Cs-137/Sr-90 ratios in cereals and milk, while the decrease in December 1965 is ascribed to relatively high Sr-90 levels in the milk from this month (cf. also fig. 5.7.2). It is remarkable that the ratios in South Jutland (zone IV) are definetely higher than those in Bornholm (zone VIII). This might be explained by the lower fall-out rate in zone VIII (cf. 4.1) in combination with the greater availability of Sr-90 from the soil in Bornholm as compared with zone IV.

From the total-diet sampling it is possible to estimate the mean levels of Sr-90 and Cs-137 in the Danish diet in 1965. For the period January-April 1964 the Sr-90 level in the total diet is assumed to have been equal to that measured in December 1964[9]. For the period May-September we assume the level to have corresponded to that measured in June 1965. The December 1965 figure is assumed to represent the last three months of the year. The population-weighted means of Sr-90 in total-diet samples were 28.9 pCi Sr-90/g Ca in December 1964[8], 21.4 in June 1965 and 18.3 in December 1965. Hence the mean content in the total diet in 1965 was 23.1 pCi Sr-90/g Ca or 41.1 pCi Sr-90/day.

In a similar way the Cs-137 content in the Danish diet in 1965 was estimated to be 244 pCi Cs-137/day or 64 pCi Cs-137/g K.

5.8. Sr-90 and Cs-137 in Miscellaneous Foodstuffs

5.8.1. Sr-90 and Cs-137 in meat

Pork and beef samples were collected in Copenhagen (cf. figs. 5.2.1 and 5.2.2) in three big shops in March, June and December. Table 5.8.1 shows the results.

5.8.2. Sr-90 and Cs-137 in fish, cheese and eggs

Fish samples were collected at three coastal locations, Rødvig, Hundested and Helsingør, in Sealand in June and December. Cheese and eggs were collected in Copenhagen in September. Table 5.8.2 shows the results. The S.U. level in cheese was somewhat higher than that in milk (cf. 5.1), probably because the cheese was made of milk from the beginning of 1965 and perhaps from Jutland (cf. the difference between population- and production-weighted means in 5.2). Eggs were surprisingly low in activity as compared with 1964[9]. The S.U. level in fish meat was approx. one fourth of that in sea water (cf. 7).

5.8.3. Sr-90 and Cs-137 in imported vegetable food

As in 1964[9], imported vegetable food was collected from three shop groups in Copenhagen in December 1965. Table 5.8.3 shows the results.

Table 5.8.1

Sr-90 and Cs-137 in Pork, Beef and Veal in 1965

Sort		Mar.	June	Dec.	Annual [x] mean
Pork	pCi Sr-90/kg	3.4	3.3	3.6	3.4
	S.U.	29	28	16	25
	pCi Cs-137/kg	553	615	235	505
	M.U.	149	199	80	157
Beef	pCi Sr-90/kg	3.7	5.0	3.7	4.4
	S.U.	40	44	38	42
	pCi Cs-137/kg	243	322	190	269
	M.U.	71	115	58	90
Veal	pCi Sr-90/kg	4.2	-	2.6	-
	S.U.	59	-	24	-
	pCi Cs-137/kg	290	-	101	-
	M.U.	90	-	29	-

[x] In calculating the annual mean levels it was assumed that March represented the levels in the first three Months of the year. June those in the following six and December those in the last three months.
2/3 of the meat consumed in Denmark is pork and 1/3 beef, i.e. the average Cs-137 content in Danish meat in 1965 was 426 pCi Cs-137/kg and the average Sr-90 content 3.7 pCi Sr-90/kg. The relative error of the results in the table was estimated at 20%.

Table 5.8.2

Sr-90 and Cs-137 in Fish, Cheese and Eggs Collected in 1965
in Sealand and Copenhagen

Sample	pCi Sr-90/kg	S.U.	pCi Cs-137/kg	M.U.	mg Sr/g Ca	Month
Flounder meat	1.00	1.95	48.6	13.4	2.7	June
Herring meat	0.68	1.24	55.3	16.0	1.9	June
Codfish meat	1.48	1.51	131.0	29.0	4.4	Dec.
Cheese	204	26.5	30.5	35.0	-	Sep.
Eggs	2.96	4.84	14.4	9.7	-	Sep.

The estimated errors of the results are 15-20%.

Table 5.8.3

Sr-90 and Cs-137 in Imported Vegetable Food Collected in Copenhagen in December 1965

Sort	pCi Sr-90/kg	S.U.	pCi Cs-137/kg	M.U.	mg Sr/g Ca
Orange	6.0	20.2	9.2	6.8	5.3
Lemon	11.1	31.0	19.0	10.6	26.0
Grapefruit	-	-	45.8	24.4	-
Pineapple	5.2	41.7	17.6	13.2	4.8
Peach	3.2	43.2	30.4	9.7	5.4
Banana	0.7	15.8	15.1	4.0	7.5
Grape	2.7	11.8	-	-	7.2
Date	1.8	4.3	-	-	5.9
Prune	9.9	25.7	47.8	7.0	6.3
Raisin	10.7	23.0	47.3	6.8	4.7
Fig	30.6	18.6	44.2	9.2	2.9
Apricot	70.5	70.6	31.3	2.3	2.2
Almond	57.1	38.8	569	67.5	2.3
Walnut	7.1	17.2	443	87	2.2
Hasel-nut	84.9	68.6	1750	220	6.2
Brazil nut	357.0	165.0	-	-	40.0
The estimated errors of the results are 15-20%.					

As compared with 1964, the Sr-90 levels were a little lower in 1965, whereas the Cs-137 levels were nearly the same. Nuts still showed rather high levels of Sr-90 as well as of Cs-137.

Furthermore we determined the activity content in rice and rolled oats collected in December in Copenhagen. We found 1.2 pCi Sr-90/kg (47 S.U.) and 38.1 pCi Cs-137/kg (52.0 M.U.) in rice and 32.5 pCi Sr-90/kg (10.5 S.U.) and 126.6 pCi Cs-137/kg (36.0 M.U. in rolled oats.

5.8.4. Sr-90 in drinking water

Along with the total-diet sampling in June and December 1965, 10 l of drinking water was collected in each of the 48 towns (cf. figs. 5.2.1 and 5.2.2). The 10 l water samples were bulked into eight zone samples, each comprising 60 l of water. Furthermore, 3 · 20 l of water were collected from three different parts of Copenhagen and combined to a 60 l sample. The samples were analysed, by the method used for ground water[6], for Sr-90, stable strontium and calcium

Table 5.8.4 shows the results. The Sr-90 figures in the table should be regarded as maximum figures. Sr-90 was present in the drinking water

Table 5.8.4

Sr-90 in Danish Drinking Water in 1965

	June			December		
Zone	pCi Sr-90/l	g Ca/l	mg Sr/g Ca	pCi Sr-90/l	g Ca/l	mg Sr/g Ca
I North Jutland	0.013	0.057	9.3	0.008	0.064	8.2
II East Jutland	0.044	0.068	8.2	0.024	0.077	9.7
III West Jutland	0.026	0.052	4.3	0.006	0.057	4.6
IV South Jutland	0.032	0.082	3.8	0.005	0.085	3.3
V Funen	0.022	0.118	6.8	0.005	0.121	9.0
VI Sealand	0.018	0.100	8.0	0.006	0.105	14.0
VII Lolland-Falster	0.011	0.096	32.1	0.005	0.102	33.2
VIII Bornholm	0.064	0.069	8.2	0.034	0.083	4.7
Mean	0.029	0.080	10.1	0.012	0.087	10.8
Copenhagen	0.010	0.110	18.8	0.016	0.120	17.1
Population-weighted mean	0.022	0.087	11.2	0.012	0.095	11.9
The estimated error of the Sr-90 determinations is approx. 70%, and the error of the mg Sr/g Ca ratio is approx. 16%.						

from eastern Jutland (zone II) and from Bornholm (zone VIII), whereas it is doubtful at the moment whether zones III-VII showed significant levels of Sr-90. The water from zone I and Copenhagen probably contained significant amounts of Sr-90. The activity decrease from June to December is not real, but due to an improved analytical technique in December as compared with June. It is remarkable that the Sr-90 level in drinking water is on the average lower than that measured in ground water (cf. 4.3). We suppose that this is due mainly to a removal of Sr-90 during the filtration and purification at the waterworks. In this connection it is interesting to notice that the mg Sr/g Ca ratio in drinking water was approx. twice as high as in ground water; it is especially remarkable that the drinking water from Lolland-Falster (zone VII) shows a stable Sr/Ca ratio which is an order of magnitude higher than the ratios found in western and southern Jutland (zones III-IV). A similar trend (although not so marked) in the mg Sr/g Ca ratios has been observed earlier[7, 8, 9] in vegetables. In cereals[21], however, Lolland-Falster (Abed) did not show higher mg Sr/g Ca ratios than western and southern Jutland (Studsgård, Askov and St. Jyndevad) (cf. also table 5.3.7).

5.9. Estimate of the Mean Contents of Sr-90 and Cs-137 in the Human Diet in Denmark in 1965

5.9.1. The annual quantities

The annual quantities are calculated by multiplication of the daily quantities (as stated by E. Hoff-Jørgensen, cf. Risö Report No. 63, table B[7]) by 365.

5.9.2. Milk and cream

The Sr-90 and Cs-137 contents per kg milk were calculated from the annual mean values for dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg milk $\sim$ 1 l milk, containing approx. 1.2 g Ca and 1.66 g K. Hence the mean contents in milk were 20.8 pCi Sr-90/kg and 55 pCi Cs-137/kg.

5.9.3. Cheese

1 kg of cheese contains approx. 8.5 g Ca and 1.2 g K. The Sr-90 and Cs-137 contents in cheese were calculated from these figures and from the S.U. and M.U. levels in dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg of cheese appeared to contain 147.9 pCi Sr-90 and 40 pCi Cs-137.

5.9.4. Grain products

Tables 5.9.1 and 5.9.2 show the estimates of Sr-90 and Cs-137 respectively in grain products consumed in 1965. From these tables the activity levels in grain products were estimated at 97.0 pCi Sr-90/kg and 403 pCi Cs-137/kg.

Table 5.9.1

Estimate of the Sr-90 Content in Grain Products Consumed per Capita in 1965

Type	Fraction from harvest 1964			Fraction from harvest 1965			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extration)	21.9	252	5519	7.3	111	810	6329
Wheat flour (75% extraction)	32.9	27.4	901	10.9	17.4	190	1091
Grits	5.5	56	308	1.8	32	58	366
Total	60.3	111.6	6728	20.0	52.9	1058	7786

The Sr-90 content in wheat flour (75% extraction) was calculated from the levels found in wheat grain by division by 5 [5]. The Sr-90 content in grits was calculated as approx. 40% of the level found in grain.

Table 5.9.3

Estimate of the Cs-137 Content in Grain Products Consumed per Capita in 1965

Type	Fraction from harvest 1964			Fraction from harvest 1965			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extraction)	21.9	958	20,980	7.3	311	2,270	23,250
Wheat flour (75% extraction)	32.9	189	6,218	10.9	80	872	7,090
Grits	5.5	329	1,810	1.8	110	198	2,008
Total	60.3	481	29,008	20.0	167	3340	32,348

In the previous years [9] it was found that the Cs-137 level in wheat flour (75% extraction) was approx. 50% at the level found in wheat grain. Hence the wheat grain from the 1965 harvest yields flour (75% extract.) with a Cs-137 content of approx. 80 pCi/kg. The Cs-137 content in grits was calculated as 75% of the level found in oats.

5.9.5. Potatoes

The figures in table 5.5.1 were used, i.e. 3.7 pCi Sr-90/kg and 22 pCi Cs-137/kg.

5.9.6. Vegetables

Table 5.6.9 shows the calculation of Sr-90 and Cs-137 in Danish vegetables consumed in 1965. The mean contents in vegetables were 13.8 pCi Sr-90/kg and 14 pCi Cs-137/kg.

5.9.7. Fruit

Table 5.6.10 shows the calculation of Sr-90 and Cs-137 in Danish fruit consumed in 1965. The levels in imported fruit are assumed to be equal to the mean levels found in oranges and bananas collected in Copenhagen in December 1965 (cf. table 5.8.3), i.e. 3.4 pCi Sr-90/kg and 12.6 pCi Cs-137/kg. The mean levels in Danish fruit in 1965 were 5.1 pCi Sr-90/kg and 44.1 pCi Cs-137/kg. The daily mean consumption of fruit consisted of 100 g of Danish and 40 g of foreign origin. Hence the mean contents in fruit were 4.6 pCi Sr-90/kg and 35 pCi Cs-137/kg.

5.9.8. Meat

Table 5.8.1 gives the annual mean values of Sr-90 and Cs-137 in meat: 3.7 pCi Sr-90/kg and 426 pCi Cs-137/kg.

5.9.9. Fish

The Sr-90 and Cs-137 contents in fish are shown in table 5.8.2. The means of these figures are used as country mean values for the year, i.e. 1.6 pCi Sr-90/kg and 78 pCi Cs-137/kg.

5.9.10. Eggs

The activity contents in eggs were estimated from the measurements in table 5.8.2. The levels were 3.0 pCi Sr-90/kg and 14 pCi Cs-137/kg.

5.9.11. Coffee and tea

The levels found in 1964[9] were used for 1965, i.e. 21.6 pCi Sr-90/kg and 77 pCi Cs-137/kg.

5.9.12. Drinking water

The Sr-90 mean level found in drinking water collected in June and December (cf. table 5.8.4) was used as the country mean for drinking water, i.e. 0.02 pCi Sr-90/l. The Cs-137 content in drinking water is assumed to be negligible.

Table 5.8.3

Estimated of the Mean Content of Sr-90 in Human Diet in Denmark in 1965

Type of food	Annual quantity in kg	pCi Sr-90 per kg	Total pCi Sr-90	Percentage of total Sr-90 in food
Milk and cream	164.0	20.8	3,411	23.9
Cheese	9.1	147.9	1,346	9.4
Grain products	80.3	97.0	7,786	54.5
Potatoes	73.0	3.7	270	1.9
Vegetables	43.8	13.8	604	4.2
Fruit	51.1	4.6	235	1.7
Meat	54.7	3.7	202	1.4
Fish	10.9	1.6	174	1.2
Eggs	10.9	3.0	33	0.2
Coffee and tea	5.5	21.6	119	0.8
Drinking water	548	0.02	110	0.8
Total			14,290	

The mean annual calcium intake was estimated at 620 g (approx. 200-250 g Creta praeparata). Hence the Sr-90/Ca ratio in the total diet was 28.0 S.U. in 1965.

Table 5. 9.4

Estimated of the Mean Content of Cs-137 in Human Diet in Denmark in 1965

Type of food	Annual quantity in kg	pCi Cs-137 per kg	Total pCi Cs-137	Percentage of total Cs-137 in food
Milk and cream	164.0	55	9,020	12.8
Cheese	9.1	40	364	0.5
Grain products	80.3	403	32,348	45.9
Potatoes	73.0	22	1,606	2.3
Vegetables	43.8	14	613	0.9
Fruit	51.1	35	1,788	2.5
Meat	54.7	426	23,302	33.1
Fish	10.9	78	850	1.2
Eggs	10.9	14	153	0.2
Coffee and tea	5.5	77	424	0.6
Total			70,468	

As the approximate annual intake of potassium was 1365 g, the pCi Cs-137/g K ratio was approx. 51.6. The mean daily intake in 1965 was 193 pCi Cs-137 per capita.

5.9.13. Discussion

Tables 5.9.5 and 5.9.6 show the estimates of Sr-90 and Cs-137 in the Danish diet in 1965. The figures should be compared with the levels calculated from the total-diet samplings (cf. 5.7). The Sr-90 estimates obtained by the two methods were 23.0 S.U. and 23.1 S.U. respectively, and the Cs-137 estimates were 193 pCi Cs-137/day and 244 pCi Cs-137/day.

Hence the Sr-90 estimates are in close agreement, while the Cs-137 levels differ by a factor of nearly 1.3. The main reason for this difference is that white bread consumed in the last part of 1965 contained considerably more Cs-137 than anticipated in the calculations of table 5.9.4 (cf. tables 5.9.2 and 5.4) because white bread was made of flour from previous years when the activity levels were higher than in 1965.

The relative contribution of Sr-90 from milk products increased from approx. 25% in 1964 to 23% in 1965, whereas that from grain products decreased from 66 to 54%. The contribution from potatoes, other vegetables and fruit increased from 7 to 8%, and that from the remaining diet components from 2 to 4%. The relative contribution of Cs-137 in the total diet changed as follows from 1964 to 1965: Milk products showed a decrease from 17 to 13%, grain products a slight decrease (an increase would have seemed more likely) from 47 to 46%, and meat an increase from 28 to 33%. Potatoes, other vegetables and fruit were unchanged at 6%.

6. STRONTIUM 90 AND CAESIUM 137 IN MAN IN 1965

6.1. Sr-90 in Human Bone

The collection of human vertebrae from the institutes of forensic medicine in Copenhagen and Århus was continued in 1965. As in the total-food survey (cf. 5.7), the country was divided into eight zones. The samples were divided into four age groups: new-born (< 1 month), infants (1 month - 4 years), children and teen-agers (5 - 19 years), and adults (> 19 years).

Tables 6.1.1 - 6.1.4 show the results for the four groups.

The 1965 levels were nearly equal to the levels found in 1964[9], for new-born and infants a little lower, for children and adults a little higher. As in 1964, the highest levels were found in the infant group, the lowest among adults (cf. fig. 6.1).

As in the previous years[8, 9], the mean OR: S.U. (new-born's bone)/ S.U. (mother's diet) was calculated from tables 6.1.1, 5.7.1 and 5.7.2 and Risö Report No. 107, tables 5.7.1 and 5.7.2[9] to be 0.08 (S.D.: 0.03, S.E.: 0.01). In 1963[8] we found the ratio to be 0.11 (S.D.: 0.04, S.E.: 0.01) and in 1964: 0.09 (S.D.: 0.02, S.E.: 0.01).

Table 6.1.1

Sr-90 in Bone from New-born Children (≤1 month old) in 1965

Zone	Age in days	Month of death	Sex	pCi Sr-90/g Ca	Sample No.
II	21	1	m	4.94	MK 2
II	2	1	m	3.18	MK 3
II	1	1	f	2.40	MK 4
II	2	2	m	1.89	MK 11
II	15	2	f	3.71	MK 13
II	1	3	f	1.77	MK 25
II	12	5	f	3.81	MK 45
II	1	11	f	1.58	MK 63
II	3	11	m	2.33	MK 72
II	14	12	f	2.62	MK 85
III	1	3	f	1.37	MK 22
III	1	3	m	2.16	MK 24
IV	10	3	m	3.15	MK 21
IV	8	3	m	5.10	MK 31
Mean				2.86	
S.D.				1.18	

The relative error of the results was estimated at 15%.

Table 6.1.2

Sr-90 in Bone from Infants (≦4 years old) in 1965

Zone	Age in years and months	Month of death	Sex	pCi Sr-90/g Ca	Sample No.
I	8 m	5	f	4.48	MK 42
I	1y 4 m	8	f	9.70	MK 54
II	7 m	1	m	7.11	MK 7
II	3 m	1	f	5.98	MK 10
II	2 m	2	m	4.31	MK 15
II	1y	3	f	6.61	MK 27
II	3y 6 m	3	f	9.60	MK 28
II	5 m	3	f	11.15	MK 29
II	7 m	4	m	9.28	MK 38
II	6 m	4	m	6.30	MK 40
II	2 m	5	m	3.97	MK 43
II	1y	5	m	9.04	MK 44
II	2y 10 m	5	f	7.33	MK 46
II	5 m	8	m	4.64	MK 55
II	6 m	8	-	2.94	MK 56
II	3 m	10	m	3.60	MK 64
II	1 m	11	m	2.77	MK 70
II	3 m	11	f	3.04	MK 74
II	3 m	12	-	6.10	MK 82
II	2y 9 m	12	-	5.65	MK 90
III	4 m	1	m	7.10	MK 8
III	8 m	11	m	5.76	MK 76
III	4 m	12	f	4.85	MK 84
IV	8 m	3	f	15.80	MK 30
IV	3y 6 m	11	f	7.28	MK 78
Mean				6.58	
S.D.				2.99	
The relative error of the result (S.D.) was estimated 10%.					

If the OR between S.U. in infants' bone (≧1 year, from table 6.1.2) and S.U. in the total diet (tables 5.7.1 and 5.7.2 and refs. 6, 7, 8, 9) consumed during the period of infancy is calculated, the mean ratio for the seven samples is 0.25 (S.D.: 0.06, S.E. 0.02). If the actual infant diet contains relatively more milk and less cereals than the adult diet used in the calculation, the real OR between S.U. in infants' bone and diet will be larger than 0.25 (cf. fig. 5.7.2).

Table 6.1.3

Sr-90 in Bone from Children and Teen-agers ($\leq$19 years old) in 196

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca	Sample No.
I	8	3	m	3.10	MK 19
I	17	8	f	1.70	MK 48
I	15	8	f	4.04	MK 53
I	17	11	m	7.95	MK 75
I	11	11	m	3.03	MK 77
I	18	12	m	4.18	MK 81
II	5	1	f	3.68	MK 1
II	6	1	f	4.85	MK 5
II	9	1	f	1.95	MK 9
II	8	2	m	2.24	MK 12
II	9	2	m	2.06	MK 17
II	9	3	m	4.05	MK 20
II	9	5	f	4.02	MK 47
II	11	2	m	4.88	MK 14
II	16	3	m	1.69	MK 34
II	16	3	m	4.44	MK 35
II	11	3	f	4.94	MK 36
II	11	3	f	2.76	MK 37
II	18	8	m	3.78	MK 49
II	19	8	m	3.27	MK 50
II	19	8	f	2.06	MK 51
II	13	11	f	10.50	MK 73
II	13	12	f	7.25	MK 79
III	5	3	f	4.64	MK 23
III	16	2	m	5.08	MK 18
III	19	3	m	4.10	MK 33
III	15	4	f	6.36	MK 39
III	18	8	m	4.19	MK 52
VI	18	12	m	4.29	MK 88
VI	19	10	f	4.11	MK 61
VI	19	12	m	3.10	MK 86
Mean				4.14	
S.D.				1.90	

The relative error of the results (S.D.) was estimated at approx. 10%.

Table 6.1.4

Sr-90 in Bone from Adults (>19 years old) in 1965

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca	Sample No.
I	70	10	f	3.31	MK 54
I	58	11	m	1.91	MK 71
I	57	12	f	3.54	MK 83
I	70	12	m	6.14	MK 85
II	21	2	f	2.72	MK 16
II	20	3	m	2.36	MK 26
II	66	10	f	1.77	MK 57
II	72	10	m	2.64	MK 58
II	56	10	f	1.96	MK 55
II	81	10	f	2.04	MK 56
II	67	10	m	2.17	MK 59
II	62	11	m	1.56	MK 66
II	57	11	f	3.52	MK 67
II	77	11	f	2.29	MK 69
II	65	12	f	1.80	MK 89
II	59	12	m	1.83	MK 100
III	33	11	f	1.94	MK 65
III	62	12	m	2.70	MK 80
IV	20	3	m	3.81	MK 32
IV	70	11	f	2.23	MK 68
VI	23	12	m	4.10	MK 87
VI	27	10	m	1.92	MK 60
VI	21	10	-	3.82	MK 62
Mean				2.69	
S.D.				1.06	

The relative error of the result (S.D.) was estimated at approx. 10%.

Table 6.1.5

Strontium-90 (pCi/g Ca) in Human Vertebrae Collected in Denmark in 1965

Age group	Number of samples	Min	Max	Median	Mean
New-born < 1 month	14	1.37	5.10	2.5	2.86
Infants ≤ 4 years	25	2.77	15.80	6.1	6.58
Children ≤ 19 years	31	1.69	10.50	4.0	4.14
Adults > 19 years	23	1.56	6.14	2.3	2.69

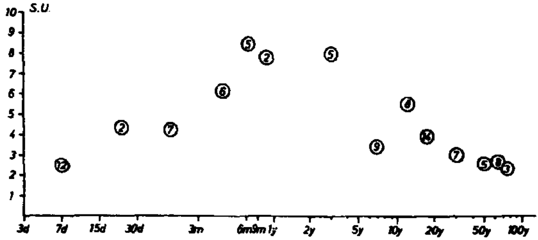

Fig. 6.1. Sr-90 in human vertebrae in 1965. (The figures in circles indicate the number of samples (and analyses).)

6.2. Cs-137 in the Human Body

In July 1963, whole-body measurements were initiated at Risö in the low-level counting room in the Health Physics Department (cf. 2.3 in Risö Report No. 85[8]). A control group from the Health Physics Department was selected and has since then been measured three or four times a year.

Table 6.2 shows the results. The control group is indicated by small letters in the table.

The annual mean value of the control group was 170 pCi Cs-137/g K. As in 1964[9], we shall consider this figure representative of the mean of the Danish population in 1965. The total-body content of Cs-137 in 1965 for a standard man containing 140 g of potassium equals $140 \cdot 170 \cdot 10^{-3}$ nCi = 23.8 nCi Cs-137, i.e. nearly the same as in 1964.

Fig. 6.2 shows the mean M.U. values (with one S.D.) for men and women measured in 1963-65.

The maximum was reached in August 1964; since then the levels have decreased. The figure also shows that the mean level in the male group was approx. 1.2 times as high as that in the female group. In 1965 as well as in 1964 the vegetarians in the male group showed relatively low levels of Cs-137 as compared with the group mean.

Table 6.2

Whole-body Measurements of Caesium-137 and Potassium in 1965

No.	Sex	Counting date	Age	Height in cm	Weight in kg	Daily milk consumption in litres	M.U. in body	Body burden nCi Cs-137	g K/kg body weight
a 144	f	8 - 3	21	164	55.0	1/4	127	16.4	2.34
b 145	m	8 - 3	33	172	64.0	3/4	249	32.5	2.04
c 146	m	10 - 3	33	193	76.5	1/4	317	34.4	2.07
d 147	m	10 - 3	28	169	66.0	1/2	166	30.7	2.80
e 149	m	11 - 3	40	170	64.0	1/2	293	40.1	2.14
f 150	m	11 - 3	33	173	74.0	1/4	230	32.2	1.89
g 151	f	11 - 3	22	171	66.5	1 litre per week	127	13.9	1.65
h 153	m	12 - 3	40	175	90.0	0	202	27.8	1.53
i 154	f	12 - 3	33	161	59.0	1/4	212	22.8	1.83
j 155	m	16 - 3	33	182	70.0	1/4	184	23.3	1.84
k 156	m	16 - 3	41	170	59.0	0	227	30.6	2.29
l 157	m	15 - 3	24	182	79.0	1	171	28.2	2.09
m 158	f	15 - 3	44	176	64.0	1/4	158	21.5	2.13
n 159	f	15 - 3	37	171	60.5	1/4	215	29.2	2.25
o 161	m	19 - 3	34	170	68.5		172	24.4	2.07
p 162	m	22 - 3	35	192	86.0	1/2	207	17.8	1.78
q 163	m	22 - 3	34	187	66.0	1/10	167	25.2	2.29
r 164	f	22 - 3	28	164	61.0	1/4	119	14.9	2.05
g 165	f	22 - 7	22	171	67.5	1 litre per week	96	10.1	1.56
n 166	f	23 - 7	37	171	61.5	1/2	209	24.4	1.89
m 167	f	22 - 7	44	176	65.5	1/4	185	20.5	1.69
r 168	f	23 - 7	28	164	62.0	1/4	92	10.2	1.79
b 169	m	23 - 7	33	172	64.0	3/4	226	27.1	1.87
p 170	m	27 - 7	35	192	85.0	1/2	218	30.0	1.62
q 171	m	27 - 7	34	187	66.0	1/10	138	20.6	2.24
k 172	m	29 - 7	41	170	81.0	0	175	22.5	2.10
s 173	f	2 - 8	19	172	65.0	0	125	15.0	1.85
i 174	f	2 - 8	33	161	59.0	1/4	151	19.0	2.13
o 175	m	3 - 8	34	170	70.0		164	21.1	1.84
a 176	f	3 - 8	21	164	55.0	1/4	124	14.6	2.14
c 178	m	12 - 8	34	193	75.0	1/4	202	31.4	2.06
e 179	m	10 - 8	40	170	65.0	1/2	268	35.2	2.02
h 180	m	13 - 8	40	175	90.0	0	180	24.7	1.52
n 182	f	2 - 11	37	171	61.0	1/2	194	24.0	2.04
r 184	f	2 - 11	28	164	61.0	1/4	126	13.4	1.74
e 185	m	2 - 11	40	170	68.0	1/2	320	38.3	1.80
s 186	f	3 - 11	19	172	66.0	0	100	13.9	2.10
m 187	f	3 - 11	44	176	65.0	1/4	181	19.9	1.69
b 188	m	4 - 11	33	172	65.0	3/4	197	29.3	2.28
c 189	m	4 - 11	33	193	75.5	1/4	169	26.3	2.06
g 190	f	4 - 11	22	171	66.0	1 litre per week	87	9.5	1.65
o 191	m	8 - 11	34	170	71.0		135	22.0	2.30
i 193	f	9 - 11	33	161	55.5	1/4	130	16.5	2.3
q 195	m	10 - 11	33	187	66.0	1/10	120	19.1	2.40
p 199	m	25 - 11	35	192	86.0	1/2	160	28.0	2.04
j 200	m	22 - 12	33	182	71.0	1/4	150	20.7	1.94
k 201	m	28 - 12	41	170	84.0	0	157	18.6	1.84

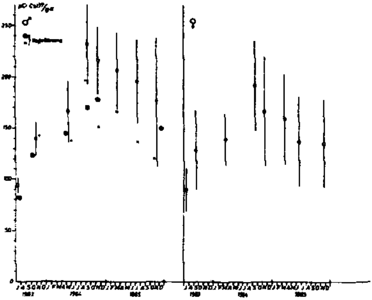

Fig. 6.2. Cs-137 mean levels in humans, 1963-65.

7. STRONTIUM 90 IN SEA WATER IN 1965

The collection of sea-water samples initiated in 1961-62 was continued in 1965. As in 1963-64, the samples, all of them surface samples, were collected in June and December around Sealand at the locations used in November-December 1962[7].

The one-litre samples from the Sound were collected all through the year and bulked into three-monthly samples. The 40 locations in the Sound were those used in 1961[6].

Tables 7.1 and 7.2 show the results.

Fig. 7 shows the mean content of Sr-90 in sea water collected since November - December 1962 at the locations in table 7.1.

Since June 1963 the mean level in the inner Danish waters has varied little from the value of 1 pCi Sr-90/l. The variation between locations seems to have been greater in summer than in winter.

The annual mean content in the Sound nearly equals that found in table 7.1.

Table 7.1

Sr-90 in Sea Water Collected around Sealand in 1965

Latitude north	Longitude east	Water	pCi Sr-90/l	pCi Sr-90/g Ca	Salinity o/oo	pCi Sr-90/l	pCi Sr-90/g Ca	Salinity o/oo
56°11' 56°06'	11°45' 11°08'	The Cattegat	1,43	3,88	27,6	0,81	2,45	24,6
55°46'	11°28'	The Cattegat	1,41	5,00	21,2	0,86	2,72	23,6
55°27' 55°17'	10°42' 10°49'	The Great Belt	1,43	5,22	20,5	0,79	2,57	23,1
55°01' 54°57'	10°31' 10°42'	The Great Belt	0,92	3,64	18,9	1,04	4,18	18,7
55°10' 54°53'	11°37' 11°28'	The Great Belt	1,00	5,67	13,3	0,69	4,27	15,6
54°42' 54°36'	10°40' 11°09'	The Femern Belt	1,03	4,29	18,0	0,75	3,04	18,4
54°33' 54°46'	11°56' 11°52'	The Baltic Sea	1,08	5,91	13,7	0,74	4,06	13,6
54°53'	12°09'	Grønsund	0,94	6,41	11,0	0,84	4,04	15,6
54°58' 55°08'	12°36' 12°17'	Fakse Bugt	1,08	8,25	9,8	0,96	6,35	11,3
		Mean	1,15	5,36	17,1	0,85	3,74	18,3
		S.D.	0,22	1,43	5,7	0,10	1,23	4,7
		S.E.	0,07	0,48	1,9	0,03	0,41	1,6

Table 7.2

Strontium-90 in the Sound in 1965 at all 40 locations
(cf. fig 7.1.1.2 in Risö Report No. 41 [6])

Sampling period	pCi Sr-90/l	pCi Sr-90/g Ca	Salinity, o/oo
Jan. - Mar. Apr. - June July - Sep. Oct. - Dec.	0,91 0,95 1,18 1,25	5,32 5,67 7,33 8,39	12,9 12,6 12,1 14,6
1965	1,07	6,18	13,0
S.D.	0,16	0,89	1,1
S.E.	0,08	0,44	0,5

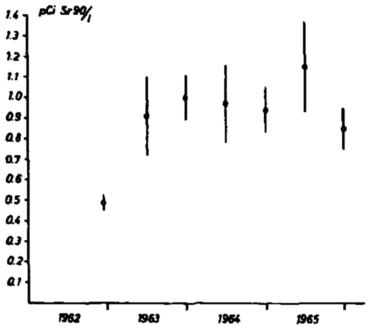

Fig. 7. The mean Sr-90 content in sea water collected in the inner Danish waters in 1962-65 (1.S.D. indicated).

8. SPECIAL SURVEYS

8.1. Meteorological Mast Experiment

As in the previous years[4-9], samples of precipitation were collected at eight different heights from the meteorological mast (cf. fig. 3.1.2.2) at Risö.

As in 1964[9], the evaporation was measured every month throughout the year by means of two control bottles placed at heights of 7 and 123 m. At the beginning of each month either bottle contained 500 ml of water + 25 ml of octanol, and at the end of the month the volumes left were measured. Calculating the ratio between the volumes found at 123 m and at 7 m, we obtained for the winter months (January - March and October - December) 1.00 $\pm$ 0.03 (one S.D.) and for the six summer months 0.98 $\pm$ 0.02. We might thus expect approx. 2% higher activity levels during summer in the upper than in the lower bottle on account of the greater evaporation in the upper bottle. The annual mean level found at 123 m was, however, 11.0 pCi Sr-90/l in 1965, while the level at 7 m was only 7.3 pCi/l, i.e. a difference of 50%. Another effect than evaporation thus still seems evident.

Table 8.1.1 shows the Sr-90 levels in the eight bottles throughout the year and table 8.1.2 the analysis of variance of the natural logarithm

Table 8.1.1

Sr-90 in the Meteorological

	0 m		7 m		23 m		39 m	
	pCi/l	mCi/km²	pCi/l	mCi/km²	pCi/l	mCi/km²	pCi/l	mCi/km²
Jan.	8.21	0.45	9.05	0.42	10.75	0.52	8.53	0.47
Feb.	19.55	0.19	22.10	0.19	21.60	0.22	19.55	0.19
Mar.	13.55	0.22	21.20	0.36	15.37	0.28	16.70	0.32
Apr.	9.37	0.65	11.93	0.71	12.90	0.55	13.30	0.80
May	11.90	0.52	13.33	0.53	14.00	0.67	15.40	0.65
June	15.75	0.68	17.79	0.81	18.89	0.84	21.01	0.77
July	6.16	0.70	6.02	0.68	6.54	0.73	6.35	0.71
Aug.	6.19	0.26	6.03	0.21	7.00	0.28	7.20	0.20
Sep.	4.13	0.17	4.30	0.16	5.17	0.19	*4.66	*0.19
Oct.	1.27	0.06	2.11	0.10	2.71	0.15	2.30	0.11
Nov.	2.22	0.12	2.38	0.12	3.15	0.12	2.74	0.12
Dec.	1.58	0.18	1.54	0.17	2.30	0.23	2.28	0.26
1965	$\bar{x}$ 6.47 649 mm	4.20 Σ	$\bar{x}$ 7.28 613 mm	4.46 Σ	$\bar{x}$ 7.86 608 mm	4.78 Σ	$\bar{x}$ 7.93 604 mm	4.79 Σ

$\bar{x} = \frac{\Sigma\, mCi/km^2 \cdot 10^3}{mm\ precipitation}$ pCi/l. The coefficient of variation of the pCi/l figures was 15% and that of the mCi/km² figures 20%.

Table 8.1.2

Analysis of Variance of ln pCi Sr-90/l in Precipitation Collected in the Meteorological Mast in 1965 (from table 8.1.1)

Variation	n/96 SSD	f	s^2	v^2	P
Between locations	1.6093	7	0.2299	10.95	> 99.95%
Between months	61.3953	11	5.5813	265.78	> 99.95%
Remainder	1.5777	75	0.0210		
Total	64.5823				
η = 0.15					

Mast in 1965

56 m		72 m		96 m		123 m		Mean	
pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2
10.22	0.53	8.37	0.47	9.49	0.50	11.40	0.42	9.63	0.47
25.80	0.19	27.25	0.28	43.10	0.32	33.90	0.26	26.61	0.23
18.40	0.35	16.60	0.35	17.50	0.41	26.88	0.49	18.28	0.35
12.77	0.52	13.22	0.75	13.69	0.95	14.60	0.78	12.72	0.71
15.00	0.54	14.20	0.59	16.60	0.65	18.79	0.71	14.90	0.61
17.25	0.62	16.70	0.71	17.85	0.55	16.95	0.65	17.77	0.70
6.69	0.76	7.18	0.80	6.38	0.69	6.46	0.59	6.47	0.71
7.66	0.23	8.30	0.25	7.69	0.20	10.05	0.19	7.53	0.23
4.99	0.20	5.21	0.21	4.36	0.20	4.92	0.17	4.79	0.12
2.65	0.13	3.71	0.09	3.48	0.19	4.81	0.08	2.88	0.11
2.54	0.10	3.32	0.13	3.68	0.12	3.97	0.06	3.00	0.11
1.91	0.21	1.92	0.14	*2.23	*0.20	2.42	0.10	2.02	0.19
$\bar{x}$ 7.71 568 mm	4.38 Σ	$\bar{x}$ 8.70 546 mm	4.75 Σ	$\bar{x}$ 8.65 576 mm	4.98 Σ	$\bar{x}$ 10.95 411 mm	4.50 Σ	$\bar{x}$ 8.19 563 mm	4.61 Σ

Table 8.1.3

Analysis of Variance of ln mCi Sr-90/km^2 in Precipitation
Collected in the Meteorological Mast in 1965
(from table 8.1.1)

Variation	n/96 SSD	f	s^2	v^2	P
Between locations	0.5885	7	0.0841	2.14	> 95%
Between months	44.9365	11	4.0851	103.68	>99.95%
Remainder	2.9579	75			
Total	48.4829				
η = 0.20					

of the pCi Sr-90/l figures. As in previous years, the variations between heights (as well as those between months) were highly significant (P> 99.95%).

Table 8.1.3 shows that the variation between locations was probably significant if instead we consider the mCi/km^2 figures in table 8.1.1. The accumulated fall-out in the upper part of the meteorological mast was thus 1.07 times the level found at 0 m. A possible explanation of the phenomenon has been published elsewhere[22].

The mean amount of precipitation in the eight bottles on the mast was 563 mm in 1965, i.e. 80% of the level measured in rain bottles at ground level at Risö (cf. table 3.2.4.1), but equal to the amount found in the 1 m^2 rain collector at Risö (cf. table 3.2.4.3). As the total evaporation from the bottles on the meteorological mast is calculated to be less than 10%, the difference between the amounts of precipitation obtained by the different sampling systems at Risö must have other reasons than evaporation.

In June-July, eight Gelmann pumps, each furnished with a 9 cm GFA glass-fibre filter transmitting approx. 1700 m^3 air per month, were installed in the meteorological mast at the eight locations of the rain bottles. Table 8.1.4 shows the results of the γ-determinations of Zr-95 (from the Chinese explosion on May 14th, 1965) and of Cs-137. The upper stations in the mast clearly show higher levels than the lower, in agreement with the Sr-90 rain-water observations. It is remarkable that the Zr-95/Cs-137 ratio also increases with height, just as observed earlier for the Sr-89/Sr-90 ratio in precipitation[23].

Table 8.1.4

γ-Measurements of Air Filters from the Meteorological Mast in June-July 1965

Height	pCi Zr-95/10^3 m^3	pCi Cs-137/10^3 m^3	Zr-95/Cs-137
0 m	0.6	5.9	0.10
7 m	0.8	7.7	0.10
23 m	1.0	8.5	0.12
39 m	0.2	5.3	0.04
56 m	2.3	9.4	0.24
72 m	1.5	11.8	0.13
96 m	2.2	10.6	0.21
123 m	3.3	15.8	0.21
Mean	1.5	9.4	0.14

The relative error of the determination is estimated at 15-20%.

8.2. Levels of Sr-90 and Cs-137 in Grass and Milk from the Entire Country

In September grass and milk were collected from the state experimental farms (cf. fig. 4.1.1). (As no milk was obtainable from Virumgård, this farm was omitted from the sampling.)

Table 8.2.1 shows the Sr-90 and Cs-137 contents in grass from the sample collection. The mean Sr-90 level was in September 130 S.U. (in

Table 8.2.1

Sr-90 and Cs-137 in Grass Collected in 1965 on the State Experimental Farms

	pCi Sr-90/g Ca	pCi Cs-137/kg grass	pCi Cs-137/g K
Tylstrup	150.5	96.8	22.7
Studsgård	167.0	140.0	17.0
Ødum	110.8	158.7	27.6
Askov	104.3	161.5	22.0
St. Jyndevad	168.5	113.0	20.6
Tårnbjerg (Funen)	93.7	95.6	30.6
Tystofte	98.2	98.0	14.5
Abed	162.3	194.0	37.6
Åkirkeby	119.0	133.8	23.0
Mean	130.5	132.4	24.0
The estimated error of the figures in the table is approx. 15%.			

Table 8.2.2

Sr-90 and Cs-137 in Milk Collected in September 1965 on the State Experimental Farms

	Milk pCi Sr-90/g Ca	Milk pCi Cs-137/g K	$\frac{(S.U.)\ Milk}{(S.U.)\ Grass}$	$\frac{(M.U.)\ Milk}{(M.U.)\ Grass}$	Milk M.U./S.U.
Tylstrup	12.1	40.0	0.080	1.76	3.31
Studsgård	18.7	19.4	0.112	1.14	1.04
Ødum	15.3 ± 1.7	30.8	0.138	1.12	2.01
Askov	9.4	38.0	0.090	1.73	4.04
St. Jyndevad	11.9 ± 0.4	27.4	0.071	1.33	2.30
Tårnbjerg (Funen)	11.1 ± 1.3	14.9	0.118	0.49	1.34
Tystofte	9.5	16.3	0.097	1.12	1.72
Abed	9.8 ± 0.5	26.8	0.060	0.71	2.73
Åkirkeby	8.8	19.2	0.074	0.83	2.18
Mean	11.8	25.9	0.093	1.14	2.30
S.D.	-	-	0.025	0.43	-
S.E.	-	-	0.008	0.14	-
The error terms indicate the S.E. of the Mean of double determinations.					

1964 the September level was 270 S.U.[9]), and the mean levels at Risö (cf. table 3.2.2) in July - September 1965 were 139 S.U.

Table 8.2.2 shows the Sr-90 and Cs-137 contents in milk samples collected in September on the state experimental farms.

The mean milk levels were 11.8 S.U. and 26 M.U. In dried milk we found in September 12.4 S.U. and 30 M.U. Hence the activity levels in milk from the state experimental farms were (as in 1964[9])) in good agreement with those found in consumers' milk (cf. 5.1).

The OR between S.U. in milk and grass was 0.09 in 1965, i.e. a little higher than in the previous years[8, 9]). This was probably due to the S.U. level in the additional fodder having approached that in grass on account of the decreasing contribution of Sr-90 in the grass from direct contamination and the increasing contribution from root uptake, which mainly determines the Sr-90 levels in additional fodder such as turnips and beets.

The OR between M.U. in milk and in grass varied between 0.5 and 1.8 with a mean of 1.1, i.e. lower than in September 1964, when we found 1.6.

8.3. Sr-90 and Cs-137 in Spring Wheat Grown in Greenhouse and Open Field

As in 1962[7]), 1963[8]) and 1964[9]), grain was grown in a greenhouse and in the open field at Risö to yield information on direct contamination and root uptake of radioisotopes from fall-out.

Table 8.3

Radio-isotopes in Spring Wheat Grown in Greenhouse and in the Open Field in 1965 at Risö

	I Grown in Greenhouse. Watered with demineralized water. Harvest: Sept.		II Grown in the open field Harvest: Sept.		I/II	
	Grain	Straw	Grain	Straw	Grain	Straw
pCi Sr-90/g Ca	25.0 ± 2.3	41.9 ± 1.4	109 ± 6	148 ± 9	0.23 ± 0.02	0.28 ± 0.02
pCi Sr-90/kg	18.8 ± 1.1	168 ± 9	66.2 ± 2.2	354 ± 21	0.28 ± 0.02	0.47 ± 0.04
pCi Cs-137/g K	3.6	3.3	29.0	132.0	0.12	0.03
pCi Cs-137/kg	15.3	37.0	109.0	493.2	0.14	0.08
Accumulated fall-out by Sep. 65	44.5 mCi Sr-90/km^2		46.8 mCi Sr-90/km^2		-	
fall-out in May-Aug. 1965	O mCi Sr-90/km^2		2.3 mCi Sr-90/km^2		-	

Table 8.3 shows the results. Approx. 75% of the Sr-90 activity in grain and straw from wheat grown in the open field (S.U. figures) came from direct uptake and hence 25% from root uptake.

The root uptake of Cs-137 was approx. 13% in the grain and 5% in the straw.

The contribution from the root uptake to the Sr-90 level in wheat grain in 1965 was less than that measured for barley in 1964, probably because barley has a larger root uptake of Sr-90 than wheat[21].

8.4. Sr-90 in Hare Bones Collected at Risö

As in the previous years, samples of bones from hares shot in October-November 1965 at Risö were analysed for Sr-90. Fig. 8.4 shows the S.U. levels in hare bones from Risö since 1958. From 1964 to 1965 the level had decreased to 13.4 S.U., i.e. by a factor of nearly three.

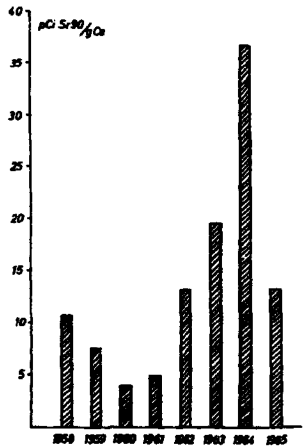

Fig. 8.4. Sr-90 in hare bones from Risö, 1958-65.

8.5. Manganese 54 in Danish Food in 1965

8.5.1. Mn-54 fall-out

As shown in table 3.3, Mn-54 was still present in air samples collected in 1965. From tables 3.3.1 in this report and in Risö Reports No. 85[8] and No. 107[9] it can be estimated that the mean concentration of Mn-54 in air in 1963 was approx. 112, in 1964: 25, and in 1965: 2.4 pCi Mn-54/10^3 m^3.

8.5.2. Mn-54 in grain

Table 8.5.1 shows the Mn-54 content in grain samples from the state experimental farms (cf. 5.3), and table 8.5.2 is the analysis of variance of the results. There was a probably significant variation between locations ($P > 97.5\%$), but none between sorts.

In this connection the relatively high levels in oats should be noted; a significant contribution from root uptake of Mn-54 for this species could not be excluded.

If we calculate the mean of the ratios $\frac{\text{pCi Mn-54/kg grain 1964}}{\text{pCi Mn-54/kg grain 1965}}$ for all species and locations and correct the 1965 figures for decay of Mn-54 ($t_{1/2}$ = 310 d), we get 3.2, i.e. a ratio equal to that of approx. 3 found for Cs-137 in grain (cf. 5.3), but higher than that observed for Sr-90: 2.0. This seems to indicate that direct contamination is the most probable mode of contamination with Mn-54 in grain as a whole[21] in Denmark.

Table 8.5.1

pCi Mn-54/kg Grain, 1965

	Rye (w)	Rye (s)	Barley	Wheat (w)	Wheat (s)	Oats
Tylstrup	33		23	86	19	64
Studsgård	102	82	74	92	159	163
Ødum	34		46	32	31	36
Askov	76		40	21		
St. Jyndevad	79		44	42		77
Blangstedgård			18	44		48
Tystofte	67		50	50	57	54
Virumgård	54		49	28	26	62
Abed	30		28	56	31	38
Åkirkeby	40		70	36		38
Mean	58		44	51		63
The estimated relative error of the γ-measurements is approx. 30%.						

Table 8.5.2

Analysis of Variance of ln pCi Mn-54/kg Grain from 1965
(from table 8.5.1)

Variation	n/40 SSD	f	s^2	v^2	P
Between locations	3.6638	9	0.4071	2.75	> 97.5%
Between sorts	0.6799	3	0.2266	1.53	70-90%
Remainder	3.7076	25	0.1483		
Total	8.0513	37			
η = 0.40					

Table 8.5.3

Mn-54 in Rye Bread Collected from the Whole

Country in 1965

pCi Mn-54/kg bread

Zone	June	December
I: North Jutland	232	183
II: East Jutland	146	112
III: West Jutland	173	77
IV: South Jutland	173	-
V: Funen	107	-
VI: Sealand	100	24
VII: Lolland-Falster	127	42
VIII: Bornholm	125	45
Mean	148	-
Copenhagen	175	61

The estimated relative error of the figures is approx. 20%.

8.5.3. Mn-54 in bread

Mn-54 was determined in the rye-bread samples collected in June and December 1965 (cf. 5.4). Table 8.5.3 shows the results. Mn-54 was not detectable in white bread from 1965. The decay-corrected mean level in rye bread from June 1965 was a factor of 2.1 lower than that in bread from June 1964, in agreement with the ratio found in 1964[9] between Mn-54 in grain from the harvests of 1963 and 1964.

8.6. Country-wide Measurement of the γ-Background in 1965

As in 1963 and 1964, the γ-background was measured in March, June, September, and December at the ten state experimental farms. Table 8.6.1 shows the results, and table 8.6.2 gives the analysis of variance. The variations between locations as well as those between months were highly significant ($P > 99.95\%$). As in the previous years[7-9], it was evidently not the fall-out that determined the variation between locations. The highest γ-levels were found at Åkirkeby, Virumgård and Tystofte, where the fall-out levels are relatively low (cf. tables 4.1.1 and 4.2.1), and the lowest γ-values were found at St. Jyndevad and Studsgård, where we have rela-

Table 8.6.1

γ-Background at the State Experimental Farms in 1965
μR/h 1965

	March	June	Sept.	Dec.	Mean
Tylstrup	4.3	5.1	6.0	5.0	5.1
Studsgård	4.5	5.8	5.1	4.7	5.0
Ødum	6.2	7.4	6.8	5.3	6.4
Askov	5.4	7.1	6.0	5.3	6.0
St. Jyndevad	4.2	5.2	4.6	4.2	4.6
Blangstedgård	6.0	6.8	6.2	5.9	6.2
Tystofte	7.1	9.1	7.7	8.0	8.0
Virumgård	8.3	9.6	8.2	8.3	8.6
Abed	5.2	6.2	4.9	5.4	5.4
Åkirkeby	(8.0)	9.0	8.6	8.0	8.4
Mean	5.9	7.1	6.4	6.0	6.4

Table 8.6.2

Analysis of Variance of the γ-Background Measurements in 1965
(from table 8.6.1)

Variation	n/40 SSD	f	s^2	v^2	P
Between locations	77.99	9	8.67	55.65	> 99.95%
Between months	9.11	3	3.04	19.51	> 99.95%
Remainder	4.05	26	0.16		
Total	91.15	38			

tively high fall-out levels. The annual mean level was 6.4 μR/h in 1965; in 1964 the level was 7.7 μR/h[9], i.e. the γ-background still decreased, although at a slower rate than from 1963 to 1964.

8.7. Sr-90 and Cs-137 in Human Milk

Human milk was collected from two donors in 1965. Donor A was from Copenhagen and was 33 years old. Her child was born on June 6 1965. The daily milk production was approx. 0.9 l, and the lactation period was June-December. Donor B was from Slangerup in North Sealand and was 27 years old. Her child was born on January 31, 1965. The daily milk production was approx. 1.2 l, and the lactation period was January-March.

The Cs-137 determinations were performed by γ-spectroscopy of the fresh milk, and Sr-90 was determined in the ash by the usual method[11]. Tables 8.7.1 and 8.7.2 show the results. The relative error of the determinations was approx. 15%. The figures in brackets are estimated figures, based on the measured neighbouring figures.

Table 8.7.1

Sr-90 and Cs-137 in Human Milk Collected from Donor A in the Period June-Dec. 1965

Period of collection	pCi Cs-137/1	M.U.	g K/1	pCi Sr-90/1	S.U.	g Ca/g ash	Cs-137/Sr-90
June 28	73.0	117	0.63				
July 5 - July 13	56.5	84	0.67	1.0	3.47	0.114	56
- 19 - - 27	38.2	91	0.43				
Aug. 1	56.9	127	0.45				
Aug. 2 - Aug. 11	54.5	129	0.42				
- 12 - - 17	59.0	95	0.62	0.8	2.93	0.145	71
- 18 - - 23	60.5	128	0.47				
- 24 - - 31	53.5	94	0.57				
Sep. 6 - Sep. 13	51.5	110	0.47				
- 14 - - 22	50.5	89	0.58	(0.3)	0.88	0.148	167
- 23 - - 28	48.5	73	0.67				
Oct. 5	55.0	92	0.60				
Oct. 6 - Oct. 11	43.0	80	0.54	(0.6)	1.82	0.135	80
- 12 - - 25	45.5	77	0.59				
Nov. 1	39.2	69	0.57				
Nov. 9 - Nov. 16	47.0	82	0.57				
- 17 - - 23	33.4	64	0.53	(0.7)	2.50	0.135	55
- 24 - - 30	34.5	60	0.58				
Dec. 10	33.0	49	0.68	(0.3)	1.05	0.127	110

Table 8.7.2

Sr-90 and Cs-137 in Human Milk Collected from Donor B in February 1965

Period of collection	pCi Cs-137/1	M.U.	g K/1	pCi Sr-90/1	S.U.	g Ca/g ash	Cs-137/Sr-90
Feb. 11 - Feb. 17	60.5	97	0.63	1.5	6.66	0.112	40
- 17 - - 22	52.1	84	0.62	1.4	7.50	0.127	37
- 22 - Mar. 2	38.3	75	0.51	0.9	3.52	0.129	43

Table 8.7.3

Sr-90 and Cs-137 in Daily Diet Samples from Milk Donor A
Collected in the Period Oct. 16-22, 1965

	pCi Sr-90/g Ca	pCi Sr-90/day	g Ca/day	mg Sr/g Ca	pCi Cs-137/day	pCi Cs-137/g K	g K/day
Oct. 16	14.5	11.0	0.76	1.92	87.9	37.6	2.34
- 17	17.0	22.9	1.35	2.38	89.6	45.5	1.97
- 18	14.4	14.2	0.99	2.38	80.9	51.0	1.59
- 19	12.4	21.7	1.75	2.15	134.7	49.0	2.75
- 20	11.2	13.3	1.19	3.20	74.4	44.0	1.69
- 21	13.3	13.3	1.00	2.63	80.4	53.0	1.52
- 22	14.0	13.3	0.95	2.36	75.9	43.0	1.76
Mean	13.8	15.7	1.14	2.43	89.1	46.2	1.95
S.D.	1.8	4.7	0.33	0.39	20.5	5.4	0.45

Table 8.7.4

A Comparison between Cs-137 Levels in Human Milk, Diet and Body, 1965

Subject	Date	Milk			Diet		Body		
		M.U.	pCi Cs-137/l	Daily excretion pCi Cs-137	M.U.	Daily intake pCi Cs-137	M.U.	pCi Cs-137/kg	body burden nCi Cs-137
A	Oct. 13	-	-	-	-	-	240	151	13.9
	Oct. 16-22	77	45.5	41.0 ± 0.5	46.2	89.1 ± 20.9	-	-	-

Diet and whole-body measurements were performed on donor A in October. The results appear in tables 8.7.3 and 8.7.4. While the S.U. and M.U. levels in the diet of the donor are in close agreement with the total-diet levels in zone VI and Copenhagen (cf. figs. 8.7.1 and 8.7.2), the total intake of food per day was on the average only 1.5 kg, i.e. approx. half that used as the daily mean per capita intake in 5.7. The percentage of the daily Cs-137 intake with food that is excreted per l milk is calculated at 51% (1 S.D.: 12%), which is a higher percentage than those observed earlier[24, 9]. The ratio $\frac{\text{M.U. in human milk}}{\text{M.U. in diet}}$ was 1.7 in October 1965, i.e. in good agreement with earlier observations[24, 9]. The OR $\frac{\text{S.U. in human milk}}{\text{S.U. in diet}}$ was 0.13 (1 S.D.: 0.02), as compared with 0.09 in 1964[9] and 0.2 in 1962[7].

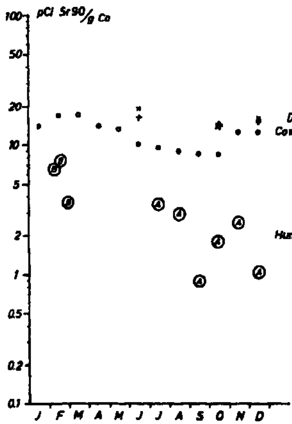

Fig. 8.7.1. S.U. in human milk, diet from Copenhagen (x), diet from zone VI (+), donors' diet (a), and cow's milk from Kalundborg (o).

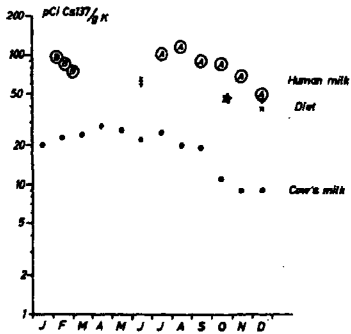

Fig. 8.7.2. M.U. in human milk, diet from Copenhagen (x), diet from zone VI (+), donors' diet (a), and cow's milk from Kalundborg (o).

9. CONCLUSION

9.1. Risö Environmental Monitoring

No increase in radioactivity in the environment originating from the operation of the Research Establishment was ascertained in 1965. As in the previous years, the variations in activity were quite independent of the distance of the sampling locations from Risö.

9.2. Nuclear-Weapon Debris in Air, Precipitation, Soil, and Ground Water

The mean content of Sr-90 in air collected in 1965 was 0.007 pCi Sr-90/m^3, i.e. approx. 33 per cent of the 1964 level. The average fall-out for the entire country in 1965 was 4.8 mCi Sr-90/km^2 or 42 per cent of the 1964 figure, and the mean concentration of Sr-90 in rain water was 6.7 pCi Sr-90/l, i.e. 35 per cent of the 1964 level.

The accumulated fall-out by the end of 1965 was approx. 57 mCi Sr-90/km^2.

The mean level of Sr-90 in Danish ground water was 0.03 pCi Sr-90/l.

The fall-out levels in Jutland, in conformity with the greater amounts of precipitation in that part of the country, were 15-25% higher than the levels found in eastern Denmark.

9.3. Sr-90 and Cs-137 in the Human Diet

The mean level of Sr-90 in Danish milk was 17.4 S.U., and the mean content of Cs-137 in Danish milk was approx. 55 pCi Cs-137/l.

The Sr-90 level was thus 70% and the Cs-137 level 49% of the 1964 levels in milk.

The Sr-90 mean content in grain from the 1965 harvest was 91 pCi Sr-90/kg. On the average, 75% of the Sr-90 in grain in 1965 was estimated to come from direct contamination. The Cs-137 mean content in grain was 200 pCi Cs-137/kg. The Sr-90 level in grain from the 1965 harvest was approx. 50% of the level found in the 1964 harvest; for Cs-137 the percentage was 35.

The mean contents of Sr-90 and Cs-137 in Danish vegetables collected in 1965 were 14 pCi Sr-90/kg (35 S.U.) and 14 pCi Cs-137/kg respectively, and in fruits 5 pCi Sr-90/kg and 44 pCi Cs-137/kg; potatoes contained 3.7 pCi Sr-90/kg and 22 pCi Cs-137/kg.

The mean levels of Sr-90 and Cs-137 in total-diet samples collected in 1965 were 23.1 S.U. or 41.1 pCi Sr-90/day and 244 pCi Cs-137/day respectively. From analyses of the individual diet components the Sr-90 level in the Danish average diet was estimated to be 23.0 S.U. and the Cs-137 intake to be 193 pCi Cs-137/day. The Sr-90 level in the Danish total diet consumed in 1965 was approx. 57% and the Cs-137 level approx. 68% of the 1964 levels.

Grain products contributed 54% and milk products 33% to the total Sr-90 intake, and 33% of the Cs-137 in the diet came from meat, 46% from grain products and 13% from milk products.

The mean observed ratio between pCi Sr-90/g Ca in the total diet and in milk for the period June 1962 - December 1965 was measured at 1.47.

The Sr-90 as well as the Cs-137 diet levels were on the average significantly higher in Jutland than in eastern Denmark.

9.4. Sr-90 and Cs-137 in Humans

The Sr-90 mean contents in human bone collected in 1965 were 2.9 S.U. in new-born, 6.6 S.U. in infants, 4.1 S.U. in children and teenagers, and 2.7 S.U. in adults (vertebrae). The 1965 bone levels for new-born were a little lower than the 1964 levels, whereas adult bone showed a little higher levels. Infants and children showed nearly the same levels in 1965 as in 1964.

The mean content of Cs-137 in the human body in 1965 was estimated from whole-body counting to be 24 nCi (170 pCi Cs-137/g K), i.e. approx. the same as the 1964 level.

9.5. Sr-90 in Sea Water

The mean content of Sr-90 in the inner Danish waters was approx. 1.0 pCi Sr-90/l in 1965, i.e. equal to the 1963 and 1964 levels.

9.6. Mn-54 in the Danish Diet

In 1965 Mn-54 was still present in rye bread, whereas the concentrations in other diet components were below the limit of detection.

9.7. Summary

The concentrations of long-lived fall-out nucleides in ground-level air and precipitation collected in 1965 were approx. one third of the levels found in 1964.

In milk and cereals produced in 1965 the Cs-137 levels were 1/2 and 1/3 respectively and the Sr-90 levels 2/3 and 1/2 of the corresponding 1964 concentrations, in agreement with the fact that Cs-137 in Danish-produced diet components mainly depends upon the fall-out rate, while Sr-90 also depends to some extent upon the accumulated fall-out; the latter, unlike the fall-out rate, was still increasing between 1964 and 1965.

The Sr-90 and Cs-137 levels in the total diet consumed in 1965 were approx. two thirds of the 1964 concentrations.

The Sr-90 concentrations in human bones were nearly unchanged from 1964 to 1965; only the bones of new-borns showed an evident decrease.

Appendix A

Calculated Sr-90 Fall-out in Denmark in 1965

Zone	mm precipitation in 1965	mCi Sr-90/km^2 in 1965	Accumulated mCi Sr-90/km^2 by the end of 1965
I: North Jutland	659	5.0	59
II: East Jutland	683	5.3	47
III: West Jutland	822	5.2	69
IV: South Jutland	850	5.5	66
V: Funen	675	4.0	45
VI: Sealand	616	3.9	51
VII: Lolland-Falster	641	4.6	49
VIII: Bornholm	655	4.8	51
Area-weighted mean	714	4.8	57

The amounts of precipitation were obtained from ref. 17. The fall-out rate in 1965 was calculated from table 4.1.1 (Askov was included in both zone III and zone IV) and from the amounts of precipitation in the zones. The accumulated fall-out in the zones was calculated from tables 4.2.1 and 4.1.1 on the assumption that the Sr-90 soil levels at the farms were representative of the zones in which the farms were located.

Appendix B

Statistical Information on Population Density, Area of the Zones and Milk, Grain, Vegetable, and Fruit Production in the Zones

Zone	Area in km^2 26)	Population in thousands 26)	Annual milk production in mega-kg 28)	Wheat area in km^2 25)	Rye area in km^2 25)	Potato area in km^2 25)	Vegetable[xx] area in km^2 27)	Fruit area in km^2 27)
I: North Jutland	7,553	502	848					
II: East Jutland	7,338	744	1,365					
III: West Jutland	10,779	552	757	427	880	570	24	18
IV: South Jutland	3,964	221	369					
V: Funen	3,482	414	505				25	38
VI: Sealand	7,542	1,973[x]	786					
VII: Lolland-Falster	1,798	132	155	919	279	70	39	45
VIII: Bornholm	588	48	74					
Total	43,044	4,586	4,857	1346	1159	640	88	101

x 1,322,000 people were living in Greater Copenhagen and 651,000 in the remaining part of Sealand.

xx Only horticultural holdings were included.

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